Dissertation on

A STUDY ON THE BRANCHING PATTERN AND VARIATIONS OF THE COELIAC ARTERY AND ITS BRANCHES

Submitted in partial fulfillment for

M.D. DEGREE EXAMINATION
BRANCH-XXIII, ANATOMY

Upgraded Institute of Anatomy

Madras Medical College & Rajiv Gandhi Government General Hospital

Chennai-600 003

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

CHENNAI-600 032

TAMILNADU

APRIL 2015

CERTIFICATE

This is to certify that this dissertation entitled

“A STUDY ON THE BRANCHING PATTERN AND VARIATIONS OF THE COELIAC ARTERY AND ITS BRANCHES”

is a bonafide record of the research work done by **Dr.E.SRIVIDHYA,** Post graduate in the Institute of Anatomy, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai-03, in partial fulfillment of the regulations laid down by The Tamil Nadu Dr. M.G.R. Medical University for the award of M.D. Degree Branch XXIII- Anatomy, under my guidance and supervision during the academic year 2012-2015.

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INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE, CHENNAI -3

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CERTIFICATE OF APPROVAL

To
Dr.E.Srividhya,
I year, M.D.Anatomy PG,
Madras Medical College, Chennai-3.

Dear E.Srividhya

The Institutional Ethics committee of Madras Medical College, reviewed and discussed your application for approval of the proposal entitled "A study on the branching pattern and variations of the Coeliac Artery and its branches " No.09062013.

The following members of Ethics Committee were present in the meeting held on 11.06.2013 conducted at Madras Medical College, Chennai -3.

1. Dr.SivaKumar, MS FICS FAIS --- Chairperson
2. Prof. R. Nandhini MD -- Member Secretary
   Director, Instt. of Pharmacology ,MMC, Ch-3
3. Prof. Shyamraj MD -- Member
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4. Prof. P. Karkuzhali. MD -- Member
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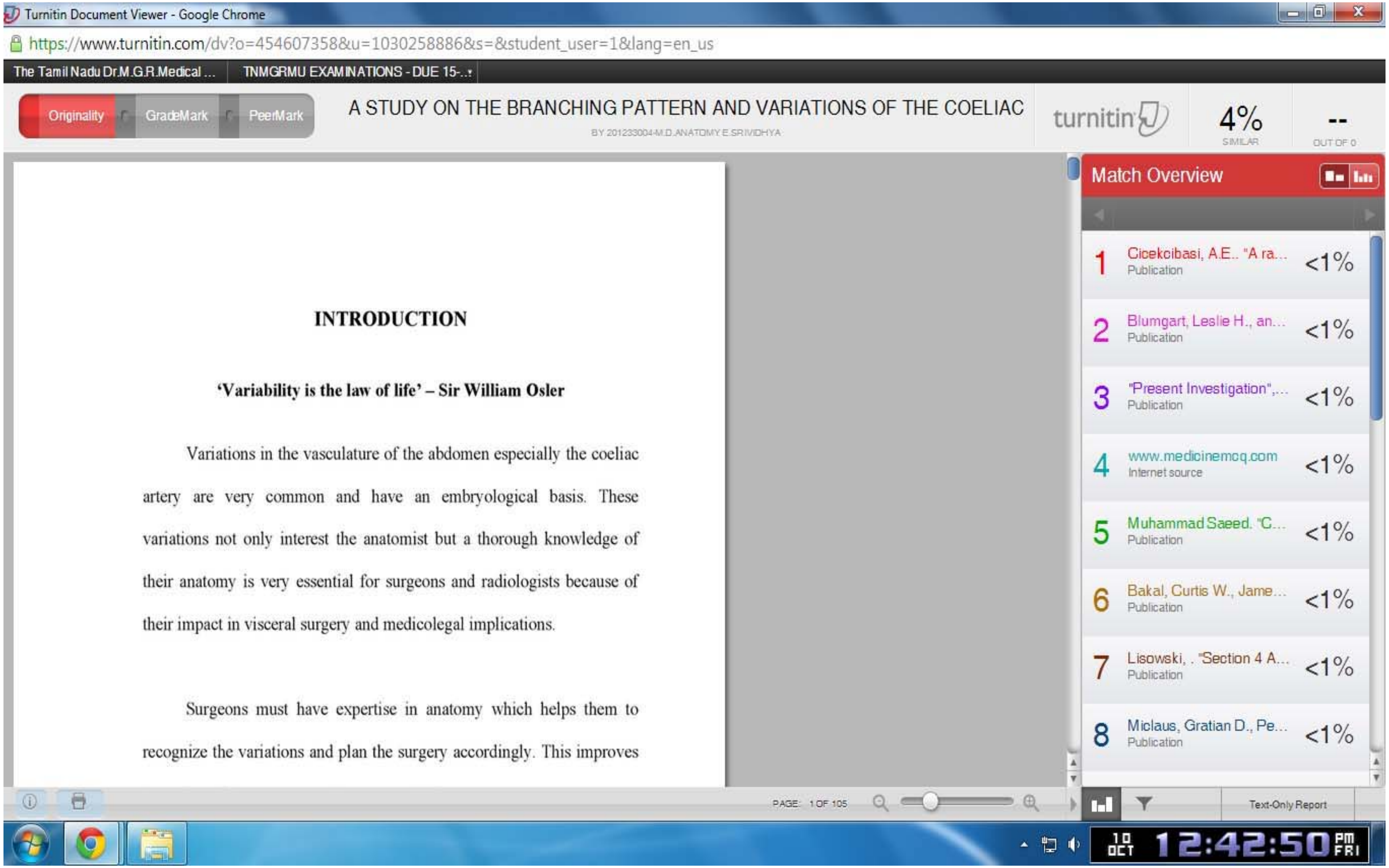
5. Prof. A. Radhakrishnan MD -- Member
   Prof of Internal Medicine, MMC, Ch-3
6. Prof. S. Deivanayagam MS -- Member
   Prof of Surgery, MMC, Ch-3
7. Thiru. S. Govindsamy. BABL -- Lawyer
8. Tmt. Arnold Saulina MA MSW -- Social Scientist

We approve the proposal to be conducted in its presented form.

Sd/ Chairman & Other Members

The Institutional Ethics Committee expects to be informed about the progress of the study, and SAE occurring in the course of the study, any changes in the protocol and patients information / informed consent and asks to be provided a copy of the final report.

R.Nadin 24/6/13
Member Secretary, Ethics Committee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INTRODUCTION
'Variability is the law of life' – Sir William Osler
Variations in the vasculature of the abdomen especially the coeliac artery are very common and have an embryological basis. These variations not only interest the anatomist but a thorough knowledge of their anatomy is very essential for surgeons and radiologists because of their impact in visceral surgery and medicolegal implications.
Surgeons must have expertise in anatomy which helps them to recognize the variations and plan the surgery accordingly. This improves
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ACKNOWLEDGEMENT

I wish to express exquisite thankfulness and gratitude to my most respected teacher and guide **Dr. Mrs. Sudha Seshayyan, M.S., Director and Professor**, Institute of Anatomy, Madras Medical College**,** Chennai – 3, for her valuable guidance, persistent support and quest for perfection which has made this dissertation take its present shape.

I am thankful to **Dr.R.Vimala M.D., Dean**, Madras Medical College, Chennai – 3 for permitting me to avail the facilities in this college for performing this study.

My heartfelt thanks to **Dr.B.Chezhian, Dr.V.Lokanayaki, Dr.B.Santhi,** Associate Professors, **Dr.V.Lakshmi**, **Dr.T.Anitha, Dr.P.Kanagavalli, Dr.J.Sreevidya, Dr.Elamathi Bose, Dr.S.Arrchana**, Assistant Professors, Institute of Anatomy, Madras Medical College, Chennai for their valuable suggestions and encouragement throughout the study.

My gratefulness to **Dr.K.Vanitha**, Director, Barnard Institute of Radiology, Govt. General Hospital, Chennai – 3 , for the help in radiological study.

I earnestly thank my seniors **Dr.K.Arumugam, Dr.P.Radhakrishnan** and my helpful juniors **Dr.S.Keerti, Dr.P.R.Prefulla, Dr.N.V.Ganga,** and other members of faculty who have been supportive and encouraging throughout the study.

I extend my heartfelt thanks to my colleagues **Dr.M.Anuradha, Dr.B.J.Bhuvaneswari,** and **Dr.S.Elizabeth Priyadarisini** for their constant encouragement and unstinted co-operation.

I'm especially thankful to **Mr.Mathews and Mr.Senthilkumar**, technicians, who extended great support for this study and all other **staff members** including **Mr.Jagadeesan, Mr.Maneesh,** and **Mr.Devaraj** for helping me to carry out the study.

I'm grateful to **my family members** for their encouragement.

I'm especially grateful to **my Mother** who has helped making this study a reality.

Above all, I thank the **ALMIGHTY GOD** who has showered His choicest blessings on me and guided me in every step of the dissertation.

LEGEND

AA	**-**	Abdominal Aorta
CA	**-**	Coeliac artery
CHA	**-**	Common Hepatic Artery
DPA	**-**	Dorsal Pancreatic Artery
GDA	**-**	Gastro Duodenal Artery
LGA	**-**	Left Gastric Artery
LHA	**-**	Left Hepatic Artery
LIPA	**-**	Left Inferior Phrenic Artery
MAL	**-**	Median Arcuate Ligament
PHA	**-**	Proper Hepatic Artery
RGA	**-**	Right Gastric Artery
RHA	**-**	Right Hepatic Artery
RIPA	**-**	Right Inferior Phrenic Artery
SA	**-**	Splenic Artery
SMA	**-**	Superior Mesenteric Artery
PV	**-**	Portal vein

CONTENTS

ABSTRACT

A STUDY ON THE BRANCHING PATTERN AND VARIATIONS OF THE COELIAC ARTERY AND ITS BRANCHES

Coeliac artery is the major source of blood supply to the supracolic abdominal compartment. It commonly divides into left gastric, splenic and common hepatic arteries. Variations in its origin and branching pattern are frequently observed during cadaveric dissection and radiological imaging. These variations although asymptomatic become significant in patients undergoing diagnostic angiography and invasive procedures of the abdomen.

In the present study the coeliac artery was complete with all three branches emerging from it in 78% and had aberrant branches in 22%. The aberrant branches encountered were the right and left inferior phrenic arteries and the dorsal pancreatic artery. Replaced left hepatic artery arising from left gastric artery was observed in 4%. In 2% of the specimens the common hepatic artery quadrifurcated into left hepatic artery, right hepatic artery, gastroduodenal artery and cystic artery.

The observations made in this study could help surgeons minimize iotrogenic injury during abdominal surgeries. It may also facilitate accurate radiological interpretation

Key words: Coeliac artery, Hepatic artery, Inferior phrenic artery, Dorsal pancreatic artery.

INTRODUCTION

‘Variability is the law of life’ – Sir William Osler

Variations in the vasculature of the abdomen especially the coeliac artery are very common and have an embryological basis. These variations not only interest the anatomist but a thorough knowledge of their anatomy is very essential for surgeons and radiologists because of their impact in visceral surgery and medicolegal implications.

Surgeons must have expertise in anatomy which helps them to recognize the variations and plan the surgery accordingly. This improves the safety of the surgery and lowers morbidity.

The value of knowledge of arterial anatomy of the abdomen has increased immensely with the introduction of laparoscopic procedures of the abdomen where the surgical field of vision is limited and mistakes are common. Ligation of a variant artery with subsequent ischemia of the part it supplies can have serious consequences on the patient.

The importance of anatomy of visceral vasculature has increased furthermore with the introduction of organ transplantation. In the era of computerized surgery, anatomy becomes indispensable.

Coeliac artery is the artery supplying the infradiaphragmatic part of the foregut namely the stomach, the part of duodenum till the opening of common bile duct, liver, pancreas, spleen.

The coeliac artery is a wide branch, approximately 1.25 cm long, from the ventral aspect of abdominal aorta; just below the aortic opening of the diaphragm. It passes horizontally forward and to the right, superior to the splenic vein and pancreas and divides into three branches

1) Left gastric artery
2) Common hepatic artery
3) Splenic artery

One or both the right and left inferior phrenic arteries may originate from coeliac artery. The coeliac artery and superior mesenteric artery may originate from a common trunk from the aorta or the classic branches of the coeliac artery may arise separately from the aorta.

THE LEFT GASTRIC ARTERY

Left gastric artery is the smallest of the branches of coeliac artery. It ascends towards the cardiac end of the stomach. On reaching it, the artery gives off two or three oesophageal branches. It then arches forward to reach the lesser curvature of the stomach dragging a fold of peritoneum with it – the left gastropancreatic fold. Situated between the layers of the lesser omentum, it descends along the lesser curvature of the stomach and anastomoses with the right gastric artery. Gastric, oesophageal, aberrant left hepatic artery (accessory or replaced) arise from it.

THE SPLENIC ARTERY

Splenic artery is the largest branch. It takes a tortuous course to left along the upper border of the pancreas, crossing the left crus of the diaphragm, the left suprarenal gland and half the breadth of left kidney.

It then reaches the hilum of spleen by passing between the layers of lieno-renal ligament and divides into five or more segmental branches. Pancreatic branches, short gastric and left gastroepiploic artery emerge from it.

THE COMMON HEPATIC ARTERY

It takes a course to the right along the upper border of the pancreas and reaches the front of portal vein. It then divides into two limbs, an ascending limb- the proper hepatic artery and a descending limb- the gastroduodenal artery. Situated between the layers of lesser omentum the proper hepatic artery reaches the porta hepatis. There it divides into the right and the left hepatic artery which supplies the corresponding lobes of the liver. The right gastric artery arises from proper hepatic artery. The common hepatic artery may originate from superior mesenteric artery or directly from aorta. The right hepatic artery may arise from superior mesenteric artery. The left hepatic artery may arise from left gastric artery.

These arteries when present along with the usual branches are called accessory hepatic arteries. When they replace the usual branches, they are called replaced hepatic arteries.

THE INFERIOR PHRENIC ARTERIES

They are the two small arteries, the right inferior phrenic artery and left inferior phrenic artery. They supply the diaphragm. They may take origin independently from the aorta, or by a common trunk either from the aorta or the coeliac artery. Sometimes one artery arises from the aorta and the other from right or left renal artery.

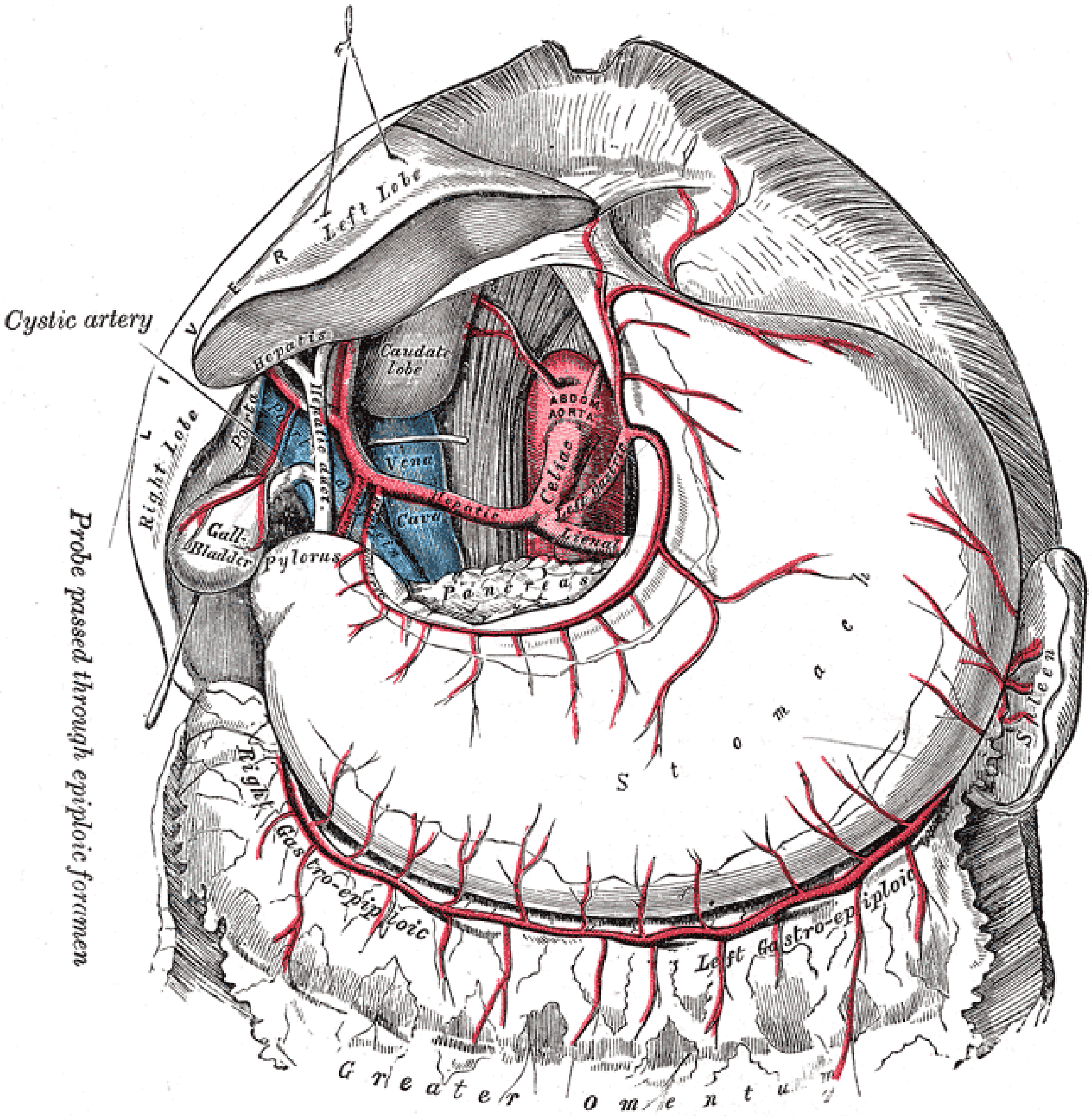
THE GASTRODUODENAL ARTERY

It arises from the common hepatic artery, behind or above the first part of duodenum. It descends between the first part of the duodenum and the neck of the pancreas. It lies usually to the left of bile duct or in front of it. It divides into superior pancreatico duodenal and right gastro epiploic arteries at the lower border of first part of duodenum.

THE DORSAL PANCREATIC ARTERY

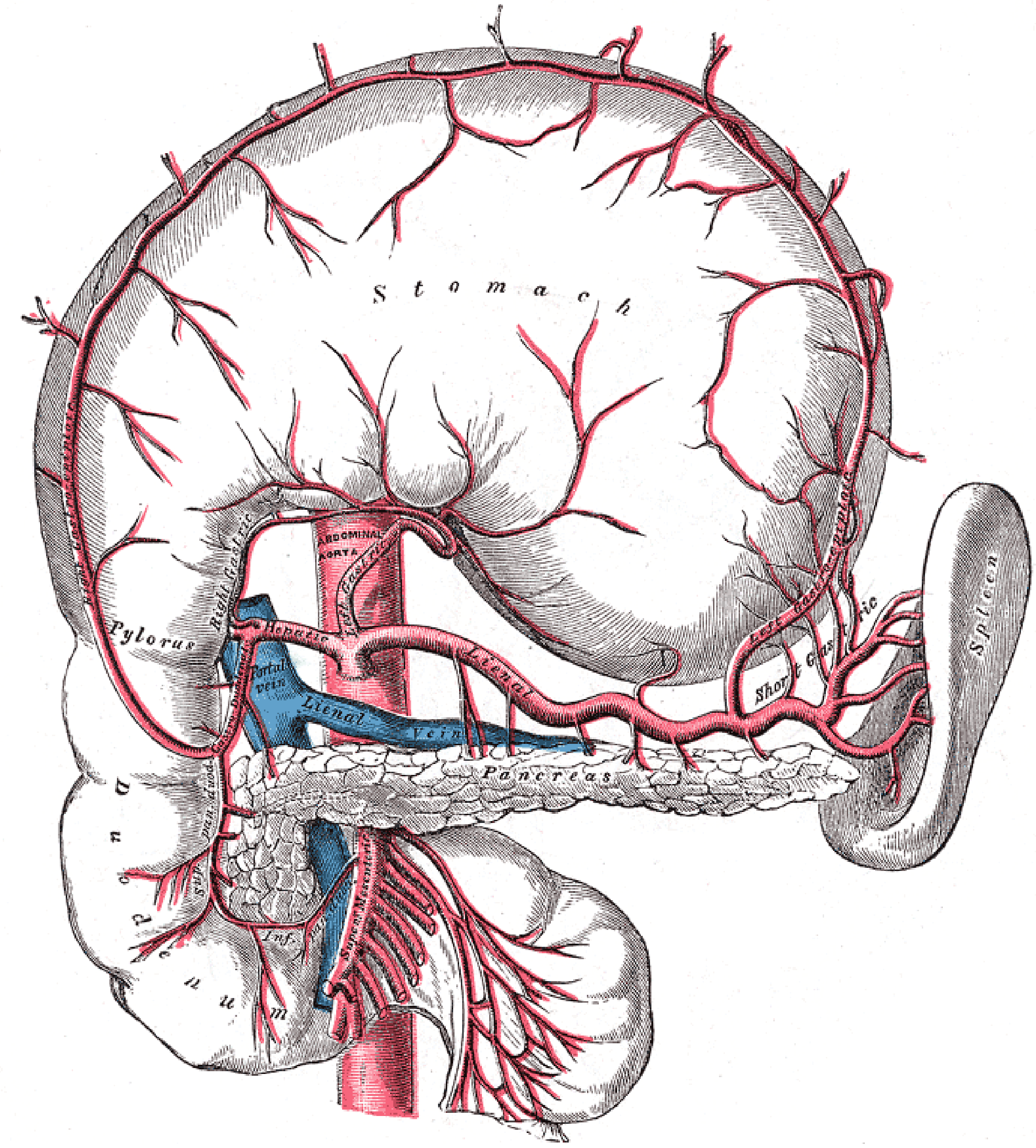
It arises from splenic artery as it runs along the upper border of the pancreas. It supplies the neck of the pancreas. It may arise from superior mesenteric, middle colic, hepatic or coeliac artery.

Coeliac artery and its branches

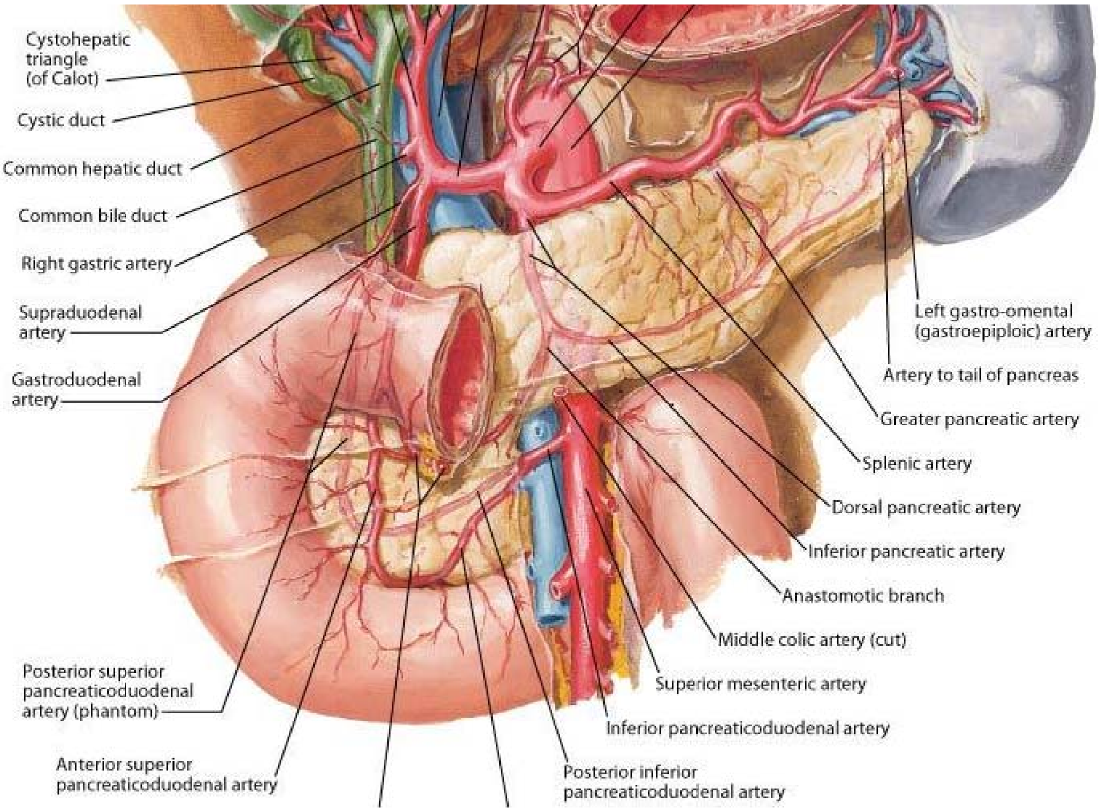


Coeliac artery and its branches - Stomach reflected

to show the entire course of splenic artery



Coeliac artery and its branches. Diagram to show the Dorsal pancreatic artery

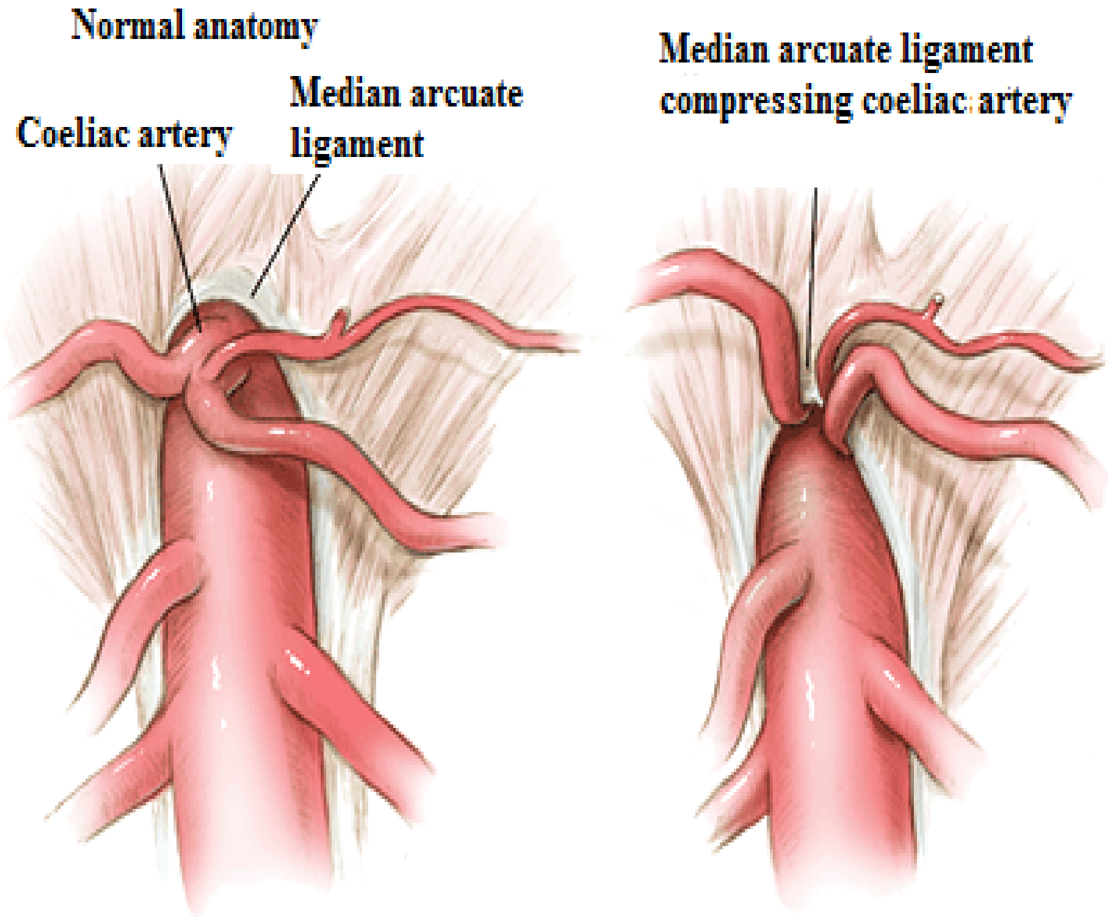


MEDIAN ARCUATE LIGAMENT

The medial tendinous margins of the right and left diaphragmatic crura meet in the median plane at the level of twelfth thoracic vertebra to form the median arcuate ligament. It forms a fibrous arch across the front of the aorta. Usually it is poorly defined. It is highly variable in position, shape, size and connective tissue content. It may be a definitive cord of 1 to 3 mm diameter or may be amorphous and hard to identify. Median arcuate ligament usually crosses the aorta above the level of origin of coeliac artery.

In some individuals (33% according to Harold H. Lindner et al[10]), it crosses at or below the level of origin of coeliac artery. This causes pathologic compression of coeliac artery and results in coeliac artery compression syndrome. The cause for this compression is either a high origin of coeliac artery or lower position of median arcuate ligament. In adults the position of coeliac artery is not consistent. This is because of high cervical origin and variable caudal migration during embryonic development. A high origin of the coeliac artery with the inferior phrenic arteries taking origin from it, frequently contributes to the entrapment syndrome. In women the coeliac artery takes origin at a more cephalic level than men.

Median arcuate ligament of the diaphragm



Aim of the study

AIM OF THE STUDY

Ligation of an abnormal artery causes ischemia of the part it supplies. This can cause unnecessary post-operative complication and sometimes even death of the patient on table. Knowing the anatomy and the possible variations pre-operatively reduces iotrogenic injury. Knowledge of branching pattern of coeliac artery is essential as it decides the plane of resection in liver transplantation surgeries. It is also essential for appropriate placement of chemo therapy pump to avoid misperfusion, chemo toxicity and bleeding.

Post-operative complications are increased in transplant recipients with variant anatomy. Such patients require extra care during pre-operative evaluation and planning of surgery. Anatomy of coeliac artery and its branches is of supreme importance in oesophageal, gastric, pancreatic, hepatobiliary malignancies where the surgery involves resection of the affected part and preservation of the unaffected part.

Therefore a thorough knowledge about the normal and variant anatomy of coeliac artery and its branches becomes indispensable in any invasive procedure of the abdomen. The present study aims at observing the coeliac artery and its branches and the variations in its branching pattern.

PARAMETERS:

LEVEL OF ORIGIN OF COELIAC ARTERY

- Upper border of T_{12}
- Lower border of T_{12}
- Intervertebral disc between T_{12} and L_1
- Upper border of L_1

ORIGIN OF COELIAC ARTERY IN RELATION TO THE MEDIAN ARCUATE LIGAMENT OF THE DIAPHRAGM

- Below the level of median arcuate ligament
- At the level of median arcuate ligament
- Above the level of median arcuate ligament

LENGTH OF COELIAC ARTERY FROM ITS ORIGIN TO EMERGENCE OF FIRST BRANCH

TYPE OF COELIAC ARTERY

- Complete:
    - Left Gastric, splenic, common hepatic
- Incomplete:

- Hepatosplenic with left gastric artery from aorta
- Gastrosplenic with common hepatic artery from superior mesenteric artery or aorta
- Hepatogastric with splenic artery from aorta

➢ Coeliacomesenteric artery

➢ Absent coeliac artery

➢ Coeliac artery with aberrant branches.

BRANCHES OF COELIAC ARTERY

➢ SOURCE OF LEFT GASTRIC ARTERY

- From coeliac artery
- From aorta

➢ SOURCE OF SPLENIC ARTERY

- From coeliac artery
- From aorta

➢ SOURCE OF COMMON HEPATIC ARTERY

- From coeliac artery
- From aorta
- From superior mesenteric artery

BRANCHES OF COMMON HEPATIC ARTERY

- SOURCE OF LEFT HEPATIC ARTERY
  - From proper hepatic artery
  - From left gastric artery
  - From common hepatic artery

- SOURCE OF RIGHT HEPATIC ARTERY
  - From proper hepatic artery
  - From superior mesenteric artery
  - From common hepatic artery

OTHER/ABERRANT BRANCHES OF COELIAC ARTERY

- RIGHT INFERIOR PHRENIC ARTERY
  - Present
  - Absent

- LEFT INFERIOR PHRENIC ARTERY
  - Present
  - Absent

- GASTRODUODENAL ARTERY
    - Present
    - Absent

- DORSAL PANCREATIC ARTERY
    - Present
    - Absent

Review of literature

REVIEW OF LITERATURE

LEVEL OF ORIGIN OF COELIAC ARTERY

J.C. Boileau Grant[5] [1958] stated that the CA takes origin from AA at the level of twelfth thoracic vertebra.

Bulent Yalcin et al[6] [2004] reported a case of 25 year old woman where the CA originated at the level of intervertebral disc between T_{12} and L_1.

Pushpalatha[25] [2006] reported that the CA took origin at the level of upper border of T_{12} in 6% of cases; lower border of T_{12} in 66% of cases; between T_{12} and L_1 in 4% of cases; upper border of L_1 in 24% of cases.

Susan Standring[39] [2008] stated that the origin of CA from AA is at the level of T_{12} / L_1 vertebra.

S.R. Nayak et al[22] [2008] reported a case where the CA originated from AA at the level of L_1 vertebra.

Kalthur S.G. et al[16] [2011] observed that CA originated from AA between T_{12} and L_1.

Ambica Wadhwa et al[2] [2011] reported that the CA originated from the AA at the level of intervertebral disc between T_{12} and L_1 in 73.3% and upper one-third of L_1 vertebra in 26.6%.

Chummy S. Sinnatamby[7] [2011] stated that the CA arises from AA at the level of the body of the twelfth thoracic vertebra.

Richard S. Snell[28] [2012] stated that the origin of CA is at the level of T_{12} vertebra.

ORIGIN OF COELIAC ARTERY IN RELATION TO MEDIAN ARCUATE LIGAMENT OF THE DIAPHRAGM.

J.David Dunbar[9] et al [1965] reported 27 cases with abdominal angina among which 15 patients presented with compression of CA by MAL of the diaphragm. 13 of them were relieved of the symptoms after surgical decompression. He also stated that in each case both LIPA and RIPA arose from the CA.

James H. Curl et al[12] [1970] reported abdominal angina in 39 year old female due to compression of CA and proximal SMA against the aorta by a tendinous median arcuate ligament.

Harold H. Lindner et al[10] [1971] stated that the origin of CA was at or above the median arcuate ligament in 33%. This was because the ligament had moved down in position and not because of high arterial origin; the coeliac ganglionic cuirass contributes to the compression of CA; there is higher incidence of compression in females.

Selma Petrella et al[34] [2006] reported that the MAL was distant from the origin of CA in 14.46%; the MAL was touching the origin of CA in 42.17% ; and MAL was overlapping the origin of CA in 43.37%

Susan Standring[39] [2008] stated that the origin of CA may be compressed by the right crus of the diaphragm giving the appearance of a stricture.

Chummy S. Sinnatamby[7] [2011] stated that the CA takes origin from AA a little below the MAL.

LENGTH OF COELIAC ARTERY FROM ITS ORIGIN TO EMERGENCE OF FIRST BRANCH

Benjamin Lipshutz[3] [1917] stated the range for the length of the CA to be 1 to 3 cm.

Pushpalatha[25] [2006] stated that the length of the CA was between 0.4 and 2.9 cm

Selma Petrella et al[32] [2007] found the mean length of the CA as 1.23cm in male and 1.11cm in female.

Susan Standring[39] [2008] stated that the length of CA is between 1.5 cm and 2 cm.

Ambica Wadhwa et al[2] [2011] reported that the length of CA was between 0.8 cm and 2.1 cm with maximum number of cases falling between 1cm and 1.3 cm.

Prakash et al[24] [2012] observed the length of CA to be between 1.2 cm and 1.4 cm.

Satheesha Nayak B et al[31] [2012] reported a case of 65 year old with CA of length 5cm.

TYPE OF COELIAC ARTERY

Benjamin Lipshutz[3] [1917] reported the following findings regarding the type of CA.

Complete CA which gave rise to left gastric, splenic, common hepatic branches were observed in 72.2% (Type 1)

Incomplete CA with any one of its branches arising from AA were observed in 25%. This included:

- Hepato splenic with LGA from aorta in 15% (Type 2)
- Gastro hepatic with SA from aorta in 6% (Type 3)
- Gastro splenic with CHA from aorta in 4% (Type 4)

Coeliaco mesenteric trunk was observed in 2.4%

J.C. Boileau Grant[5] [1958] stated that CA divides into three branches, the LGA, SA and CHA.

G.J. Romanes[29] [1972] stated that the CA divides into three branches the LGA, SA and CHA. He also stated that the CA maybe absent with its branches arising independently from AA.

W.Henry Hollinshead[11] [1975] stated that CA gives rise to three branches of which the LGA originates first followed by bifurcation into SA and CHA.

Vandamme JP et al[42] [1985] reported that the main branches of the CA are the LGA, CHA and SA. In most of the cases, the CA bifurcates into CHA and SA. The LGA has a variable origin sliding between the aorta, all over the CA up to trifurcation.

Shoumura S et al[35] [1991] reported the following findings regarding the type of CA based on Adachi's classification.

- Complete CA (Adachi Type 1) was observed in 90.2%.
- Hepatosplenic trunk (Adachi Type 2) was observed in 3.8%.
- Hepatospleno mesenteric trunk (Adachi Type 3) was observed in 1%.
- Coeliacomesenteric trunk (Type 4) was observed in 0.5%
- Gastrosplenic and Hepatomesenteric trunks(Type 5) were observed in 1.6%.

- Gastrosplenic trunk and accessory RHA from SMA (Type 6) were observed in 0.5%.

- Gastrosplenic trunk and accessory RHA from Gastrosplenic trunk (Type 6) was observed in 0.5%.

- 1.5% of cases were not classified based on Adachi.

- Gastrosplenic trunk with CHA from aorta was observed in 1%

- Splenomesenteric trunk and Gastro hepatic trunk was observed in 0.5%

R.M. Jones et al[14] [2001] reported that the CA was complete in 92%. It was incomplete in 1.7%. Hepato splenic trunk with LGA from SA was observed in 1.1%. Hepato splenic trunk with LGA from AA was observed 0.6%.

Coeliaco mesenteric trunk was observed in 1.6%.

Coeliac artery was absent in 1.1%.Aberrant branches were present in 0.6%.

Muhammad Saeed et al[19] [2003] stated that the CA was complete with all the three branches (Left gastric, splenic, common hepatic) emerging from it in 88.3%. It was incomplete with LGA and SA arising from it and CHA from SMA in 1.9%. CA with aberrant branches was found in 9.6%.

Nakamura Y et al[21] [2003] reported three cases of gastrosplenic and hepatomesenteric trunks. The gastrosplenic trunk gave origin to LIPA. The LGA gave origin to LHA. Hepatomesenteric trunk gave origin to RHA.

Bulent Yalcin et al[6] [2004] reported a case of a 25 year old in which CA gave origin to four branches namely, CHA, SA, left middle suprarenal artery and a common stem consisting of LIPA and LGA.

Pushpalatha[25] [2006] reported that CA was complete in 72%; incomplete in 4%; absent in 4%; aberrant branches were present in 20%.

Selma Petrella et al[32] [2007] stated that CA was complete in 82.02% with classic trifurcation in 20.22%.

It was incomplete in 6.6%. Gastrosplenic trunk with CHA from SMA was found in 3.37%; Hepatosplenic trunk with LGA from AA was found in 2.25%; CHA from CA with LGA, SA from aorta was found in 1.12%.

CA was absent with LGA, SA, CHA directly from aorta in 1.12%. Aberrant branches were present in 7.86%. Acc. LHA from CA was found in 2.25%.

S.R. Nayak et al[22] [2008] reported a case of CA with five branches namely, LIPA, LGA, SA, CHA, and GDA.

Susan Standring[39] [2008] stated the following regarding the CA and its branches. The CA divides into LGA, SA and CHA. One or both the IPAs may arise from CA. The CA may originate from AA along with SMA as a common trunk; the CA may give rise to one or more of the branches of SMA.

M S Ugurel et al[40] [2010] reported the following findings regarding the types of CA based on Uflacker's classification.

CA was complete in 89% with all the three classic branches emerging from it. CA was incomplete in 8% (hepatosplenic 3%, hepatogastric 1%, gastrosplenic 4%). CA was absent in 1%.

They also reported hepatosplenomesenteric trunk in 1% and spleno mesenteric trunk (not described in literature) in 1% of the cases.

Soon-Young Song et al[37] [2010] reported the following findings:

Complete CA was found in 89.1%

12 specific types of CA were observed based on variations in the branching pattern.

Incomplete CA was observed in 4.66%. This included

- Hepatosplenic trunk with LGA from aorta in 4.42%
- Hepato gastric trunk with SA from aorta in 0.02 %
- Gastrosplenic trunk with CHA from aorta in 0.22%

Coeliacomesenteric trunk was observed in 1.06%

Absent CA was observed in 0.1%

Hepatomesenteric trunk with gastrosplenic trunk was observed in 2.64%.

Hepatosplenomesenteric trunk with LGA from aorta was observed in 0.68%.

Hepatomesenteric trunk with LGA and SA from aorta was observed in 0.24%.

Hepatogastric trunk with splenomesenteric trunk was observed in 0.16%

Gastrosplenomesenteric trunk with CHA from aorta was observed in 0.06%.

Splenomesenteric trunk with CHA and LGA from aorta was observed in 0.02%.

Hepatosplenic trunk with Gastromesenteric trunk was observed in 0.02%.

Mburu K S et al[18] [2010] reported the following findings regarding the type of CA.

Complete CA with LGA,SA and CHA emerging from it was observed in 61.7%; among them classical trifurcation was observed in 32.5%. Non classical trifurcation with a separate left gastric and hepatosplenic trunk was observed in 29.3%.

Incomplete CA was observed in 17.9%; among them gastro splenic with CHA from SMA was observed in 4.9%; hepato splenic with LGA from AA was observed in 13.1%

Aberrant branches were present in 20.3%

Ambica Wadhwa et al[2] [2011] reported that CA was complete in 93.3%. It was incomplete with CHA and SA from CA, and LGA from AA in 6.6%.

Rajesh B. Astik et al[26] [2011] reported a case of CA which gave origin to left superior suprarenal artery, left middle suprarenal artery, GDA and RIPA in addition to LGA, SA and CHA

Kalthur S G et al[16] [2011] reported a case of CA with four branches namely LGA, CHA, SA and DPA.

Salve V M et al[30] [2011] reported a case of CA which trifurcated into three branches. The first branch was the LIPA. The second branch consisted of LGA and replaced LHA. The third branch divided into SA and CHA.

Chummy S. Sinnatamby[7] [2011] stated that the CA gives of three branches namely the LGA, CHA and SA.

Satheesha Nayak B et al[31] [2012] reported a case of 65 year old with CA quadrifurcating into CHA, SA, LGA and LHA. The CHA gave origin to RHA and GDA.

Jyothi Krishnarajanagar Chandrachar et al[15] [2012] reported a case of CA from which LIPA and RIPA and accessory RHA originated in addition to LGA, SA and CHA.

Prakash et al[24] [2012] stated the following findings:

- CA was complete in 86%, with classic trifurcation in 10%.
- CA was incomplete in 10% which included hepatosplenic trunk with LGA from AA in 8% and gastrohepatic trunk with SA from AA in 2%
- CA was absent in 4%

Binit Sureka et al[4] [2013] reported the following findings:

- Complete CA with the LGA, SA and CHA originating from it was observed in 91%
- Incomplete CA was observed in 4.2% which included hepatosplenic trunk with LGA from aorta (2.83%) and gastrosplenic trunk with CHA from aorta (0.83%). Gastrosplenic and hepatomesenteric trunks were observed in 0.66%.

- Coeliacomesenteric trunk was observed in 0.66%.
- Hepatomesenteric trunk with LGA and SA from aorta was observed in 0.33%.
- Hepatosplenomesenteric trunk with LGA from aorta was observed in 0.16%.
- Ambiguous anatomy was observed in 3.5%.

BRANCHES OF COELIAC ARTERY

LEFT GASTRIC ARTERY

Benjamin Lipshutz[3] [1917] stated that LGA arose directly from the AA in 15% and from CA in 85%.

J.C. Boileau Grant[5] [1958] stated that LGA takes origin from CA.

G.J Romanes[29] [1972] stated that CA gives rise to LGA.

Shoumura S et al[35] [1991] reported that LGA originated from AA in 4.8% and from CA in 95.2%.

R. M. Jones et al[14] [2001] stated that LGA arose from CA in 96.7%; LGA arose from AA in 2.2%; and from SA in 1.1%.

Pushpalatha[25] [2006] reported that LGA originated directly from the AA in 4% and from CA in 96%

Selma Petrella et al[32] [2007] reported that LGA arose directly from the AA in 4.48% and from CA in 95.52%.

Randjelovic D T et al[27] [**2007**] reported that LGA emerged from AA in 1.8% and from CA in 98.2%.

Soon-Young Song et al[37] [2010] reported that LGA originated directly from AA in 5.4% and from CA in 93.3% and ambiguous anatomy was present in 1.26%.

M S Ugurel et al[40] [2010] reported that LGA arose from AA in 5% and from CA in 95%.

Mburu K S et al[18] [2010] reported that LGA originated from AA in 13.1% and from CA in 86.9%.

Ambica Wadhwa et al[2] [2011] reported that LGA emerged from AA in 6.6% and from CA in 93.3%.

Chummy S. Sinnatamby[7] [2011] stated that LGA arises from CA.

Prakash et al[24] [2012] observed the LGA to take origin from AA in 12% and from CA in 88%.

Sunita U. Sawant et al[38] [2013] stated that LGA arose from CA in 98% of the cases and LGA arose from AA in 2%.

Binit sureka et al[4] [2013] reported that LGA originated directly from AA in 3.32% and from CA in 96.68%.

SPLENIC ARTERY

Benjamin Lipshutz[3] [1917] reported that SA arose directly from AA in 6% and from CA in 94%.

J.C. Boileau Grant[5] [1958] stated that SA takes origin from CA.

G.J Romanes[29] [1972] stated that CA gives rise to SA.

Vandamme J P et al[41] [1986] reported that variations in the origin of splenic artery are very rare and that it emerges from CA.

R. M. Jones et al[14] [2001] reported that SA arose from AA in 1.6% and from CA in 98.4%.

S. K. Pandey et al[23] [2004] reported that SA originated from AA in 8.1% and from CA in 91.9%.

Pushpalatha[25] [2006] reported that SA originated from AA in 4% and from CA in 96%.

Selma Petrella et al[32] [2007] noted that SA took origin from AA in 2.24% and from CA in 97.76%.

Soon-Young Song et al[37] [2010] reported that SA arose from AA in 0.36% and from CA in 98.4% and ambiguous anatomy was present in 1.26%.

M S Ugurel et al[40] [2010] reported that SA arose from AA in 2% and from CA in 97% and as splenomesenteric trunk in 1%.

Chummy S. Sinnatamby[7] [2011] stated that SA arises from CA.

Prakash et al[24] [2012] observed that SA arose directly from AA in 6% and from CA in 94%

COMMON HEPATIC ARTERY

Benjamin Lipshutz[3] [1917] stated that CHA is given by CA in 96% and by AA in 4%.

J.C. Boileau Grant[5] [1958] stated that CHA takes origin from CA.

G.J Romanes[29] [1972] stated that CA gives rise to CHA. He also stated that CHA or accessory HA may arise from SMA.

W. Henry Hollinshead[11] [1975] stated that in 4% CHA/PHA arises from SMA/AA/LGA and in 96% it arises from CA.

Jonathan R. Hiatt et al[13] [1994] reported that CHA arose from CA in 96%; from SMA in 1.5%; and from AA in 0.2%. There was a combination of replaced or accessory LHA and replaced or accessory RHA in 2.3%.

R.M. Jones et al[14] [2001] stated that CHA arose from CA in 98.3%; from SMA in 0.6%; and from AA in 1.1%.

Muhammad Saeed et al[19] [2003] reported that CHA arose from CA in 96.2%; from SMA in 1.9%; and as double CHA both from CA and SMA in 1.9%.

Koops et al[17] [2004] reported that CHA arose from CA in 94%; from SMA in 2.8%; and from AA in 0.2%. Combined anomalous origin of LHA and RHA were present in 3%.

Pushpalatha[25] [2006] reported that CHA arose from CA in 92% and from AA 8%.

S S Abdullah et al[36] [2006] stated that CHA emerged from CA in 89.6%; from SMA in 1.6%; and from AA in 0.3%. Combined anomalous origin of LHA and RHA were present in 8.5%.

Yang S H et al[43] [2007] stated that CHA arose from CA in 97.7%; and from SMA in 2.34%.

Corinne B. Winston et al[8] [2007] reported that CHA arose from CA in 97%; from SMA in 1.5%; and from AA in 1.5%.

Selma Petrella et al[32] [2007] stated that CHA arose from CA in 95.5%; from SMA in 3.37%; and from AA in 1.12%.

M S Ugurel et al[40] [2010] stated that CHA originated from CA in 96%; from SMA in 2%; from AA in 1% and had ambiguous origin in 1%.

Mburu K S et al[18] [2010] stated that CHA originated from CA in 95.1% and from SMA in 4.9%.

Yoshitaka Okada et al[44] [2010] reported three cases in which the CHA originated from LGA.

Soon-Young Song et al[37] [2010] stated that CHA arose from CA in 96.44%, from SMA in 3%; from AA in 0.4%; and from LGA in 0.16%.

Chummy S. Sinnatamby[7] [2011] stated that CHA arises from CA and that it may also arise from SMA or AA.

Prakash et al[24] [2012] stated that CHA emerged from CA in 96%; and from AA in 4%.

Binit Sureka et al[4] [2013] stated that CHA originated from CA in 95.83%; from SMA in 1%; from AA in 0.33 %; from ambiguous dual pathway: HM trunk in 0.66%.Its origin was not determined in 2.16%.

LEFT HEPATIC ARTERY

J.C. Boileau Grant[5] [1958] stated that LHA arises from LGA in 11.5% and from PHA in 88.5%.

G.J. Romanes[29][1972] stated that LHA or accessory HA may arise from LGA.

W. Henry Hollinshead[11] [1975] stated that accessory or replaced LHA may arise from LGA.

Jonathan R. Hiatt et al[13] [1994] stated that LHA originated from PHA in 88%; replaced or accessory LHA arose from LGA in 12%.

Muhammad Saeed et al[19] [2003] stated that LHA arose from PHA in 92.4% and from LGA in 7.6%.

Koops et al[17] [2004] stated that LHA arose from PHA in 94%; from LGA in 4.3% and from CA in 1.7%.

Pushpalatha[25] [2006] stated LHA arose from PHA in 76%; from CHA in 12%; and from LGA in12%.

S S Abdullah et al[36] [2006] stated that LHA emerged from PHA in 81.1%; from CHA 2.3%; from LGA in 14.5% and from CA in 2.1%.

Randjelovic D T et al[27] [2007] stated that LHA arose from PHA in 98% and from LGA in 1.6%. Combined anomalies of LHA and RHA were present in 0.4%. They also stated that accessory LHA arose from LGA in 4.4%.

Corinne B. Winston et al[8] [2007] stated that LHA originated from PHA in 87.9%; from LGA in 7.6%; from CHA in 4.3%; and from CA in 0.2%. They also reported accessory LHA from LGA in 4%

Susan Standring[39][2008] stated that replaced or accessory LHA arises from LGA and in some cases the CHA trifurcates into LHA, RHA and GDA.

MS Ugurel et al[40] [2010] stated that LHA arose from PHA in 87%; from LGA in 12%; and from CHA in 1%. They also reported accessory LHA from LGA in 12%.

Chummy S. Sinnatamby[7] [2011] stated that LHA arises from PHA in 80% and from LGA in 20%.

Binit Sureka et al[4] [2013] stated that LHA originated from PHA in 89.1%; from LGA in 10.5%; and from AA in 0.3%. Accessory LHA originated from LGA in 7.6%.

RIGHT HEPATIC ARTERY

J.C. Boileau Grant[5] [1958] stated that RHA arose from PHA in 88.5% and from SMA in 11.5%.

W. Henry Hollinshead[11] [1975] stated that accessory or replaced RHA arises from SMA or AA/GDA/LHA.

Jonathan R Hiatt et al[13] [1994] stated that RHA emerged from PHA in 87.1% and accessory or replaced RHA arose from SMA in 12.9%.

Muhammad Saeed et al[19] [2003] stated that the RHA arose from PHA in 96.2%; and from SMA in 3.8%.

Koops et al[17] [2004] stated that the RHA emerged from PHA in 85.1%; accessory or replaced RHA originated from SMA in 13.2%. Combined anomalous origin of LHA and RHA were present in 1.7%.

Pushplalatha[25] [2006] stated that RHA arose from PHA in 76%; from CHA in 20%;and from GDA in 4%.

S S Abdullah et al[36] [2006] stated that RHA emerged from PHA in 79%; accessory or replaced RHA originated from SMA in 16.6%; and from CHA in 2.3%. Combined anomalous origin of LHA and RHA were present in 2.1%.

Selma Petrella et al[32] [2007] stated that accessory RHA arose from CA in 2.25%.

Randjelovic D T et al[27] [2007] stated that RHA arose from PHA in 98.5%; and from SMA in 1.1%. Combined anomalies of LHA and RHA were present in 0.4%.

Yang S.H et al[43] [2007] stated that RHA originated from PHA in 90.2%; and from SMA in 9.82%.

Corinne B. Winston et al[8] [2007] stated that RHA originated from PHA in 77.7%; from SMA in 13.7%; and from CHA in 3.8%. RHA arose from GDA and CA in 4.8%.

Susan Standring[39] [2008] stated that replaced or accessory RHA arises from SMA and that the CHA may trifurcate into LHA,RHA and GDA.

M S Ugurel et al[40] [2010] stated that RHA originated from PHA in 79%; from SMA in 19%; from middle colic artery in 1% and from AA in 1%. Accessory RHA was observed in 2%.

Chummy S. Sinnatamby[7] [2011] stated that the RHA may take origin from SMA in 15% and from PHA in 85%.

Binit Sureka et al[4] [2013] stated that the RHA arose from PHA in 84.9%; from SMA in 13.5%; from CA in 1.3% and from aorta in 0.3%. Accessory RHA emerged from SMA in 3.5%.

Sunita U. Sawant et al[38][2013] stated that the accessory RHA arose from SMA in 2%.

ABERRANT BRANCHES

THE LEFT INFERIOR PHRENIC ARTERY

Benjamin Lipshutz[3] [1917] stated that the LIPA arose from CA in 15.6% of cases.

Nakamura Y. et al[21] [2003] reported 3 cases of Gastrosplenic and Hepatomesenteric trunks. LIPA originated from the Gastrosplenic trunk.

Bulent Yalcin et al[6] [2004] reported a case of a 25 year old in which the common stem of LIPA and LGA originated from CA.

Selma Petrella et al[33] [2006] reported the following findings. IPA arose from CA in 34.83% of cases, among which LIPA arose in 21.35% of cases.

Pushpalatha[25] [2006] stated that LIPA arose from CA in 18% of cases.

S. R. Nayak et al[22] [2008] reported a case of CA in which it gave origin to LIPA in addition to its classic branches.

Susan Standring[39] [2008] stated that one or both the RIPA and LIPA may orginate from CA either independently or as a common stem.

Salve V.M. et al[30] [2011] reported a case of CA in which the LIPA took origin as the first branch.

Sunita U. Sawant et al[38] [2013] reported that LIPA took origin from CA in 2% of cases.

THE RIGHT INFERIOR PHRENIC ARTERY

Selma Petrella et al[33] [2006] reported the following findings. IPA arose from CA in 34.83% of cases. RIPA alone arose in 5.62% of cases.

Pushpalatha[25] [2006] stated that RIPA arose from CA in 4% of cases.

Susan Standring[39] **[2008]** stated that one or both the RIPA and LIPA may orginate from CA either independently or as a common stem.

Mburu K S et al[18] **[2010]** stated the presence of aberrant branches in 20.3% of the cases studied among which RIPA were present in 4.9% of the cases.

Rajesh B.Astik et al[26] **[2011]** reported a case where RIPA originated from CA.

THE RIGHT AND THE LEFT INFERIOR PHRENIC ARTERIES

Muhammad Saeed et al[19] **[2003]** stated that both the IPA arose directly from CA either separately or as a common stem in 9.6% of cases.

Selma Petrella et al[33] **[2006]** reported the following findings. IPA arose from CA in 34.83% of cases. Both arose from CA in 5.62% of cases. Both arteries arose as a single stem in 2.25% of cases.

Ahmet Songur et al[1] **[2010]** stated that the IPA originated from CA as a single stem in 4.2% of cases.

GASTRODUODENAL ARTERY

Benjamin Lipshutz[3] **[1917]** stated that the GDA arose from CA in 3.7% of cases.

R. M. Jones et al[14] [2001] stated that GDA arose from CA in 0.5% of cases.

Selma Petrella et al[32] [2007] stated that the GDA arose from CA in 6.74% of cases, gastro duodenocolic artery arose from CA in 1.12% of cases.

S. R. Nayak et al[22] [2008] reported a case of CA in which it gave origin to GDA in addition to its classic branches.

Mburu K S et al[18] [2010] stated the presence of aberrant branches in 20.3% of the cases studied among which GDA originated from CA in 3.3% of the cases.

Rajesh B.Astik et al[26] [2011] reported a case where GDA originated from CA.

DORSAL PANCREATIC ARTERY

W. Henry Hollinshead[11] [1975] stated that DPA arises from SA close to its origin from CA or may arise from HA or directly from CA.

Pushpalatha[25] [2006] reported the presence of DPA in 2% of the cases studied.

Mustafa Karakose et al[20] [2006] reported a case of 62 year old where the CA trifurcated into DPA, CHA, SA and the LGA originated proximal to the trifurcation.

Mburu K S et al[18] [2010] stated the presence of aberrant branches in 20.3% of the cases studied, among which DPA were present in 14.8% of the cases.

Kalthur S. G. et al[16] [2011] reported a case of CA where DPA originated from CA in addition to its classic branches.

Sunita U. Sawant et al[38] [2013] reported that the DPA took origin from CA in 2% of the cases.

Embryology

EMBRYOLOGY

The coeliac artery develops from the ventral splanchnic arteries. The ventral splanchnic arteries are segmental branches originating from the dorsal aorta on each side and supply the primitive gut. Initially they are paired. During the fourth week of intra-uterine life, they become unpaired after the fusion of dorsal aortae.

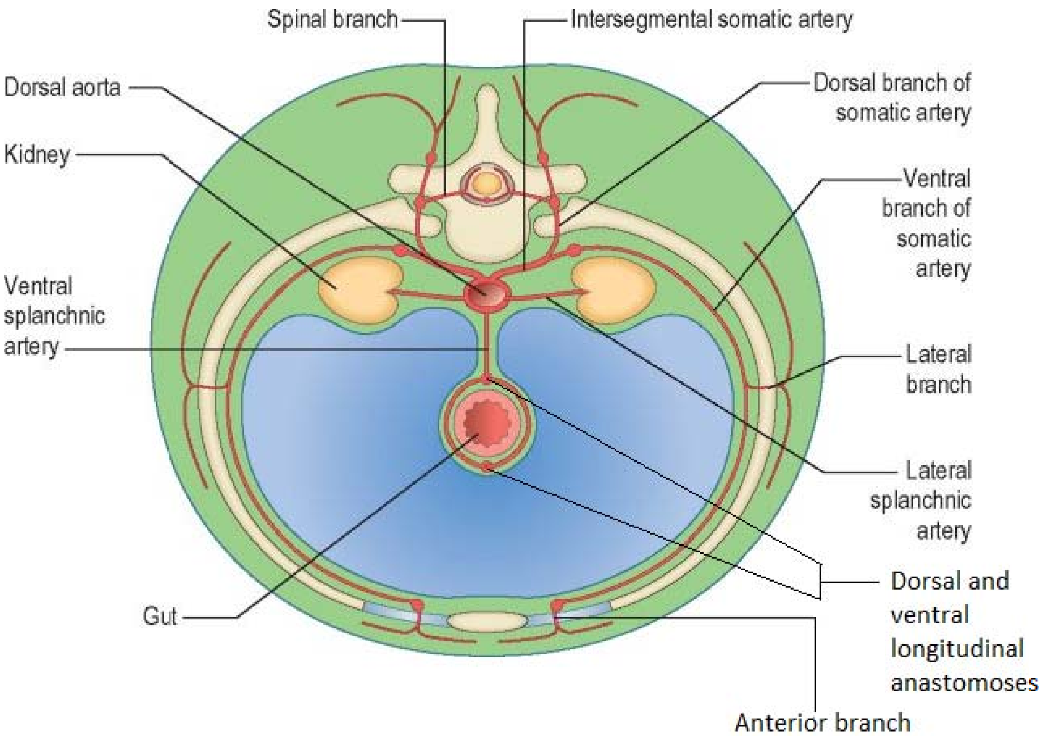
They are connected by longitudinal anastomotic channels along the dorsal and ventral aspects of the digestive tube. They form dorsal and ventral splanchnic anastomoses. After the formation of longitudinal anastomoses, only a few sub diaphragmatic ventral splanchnic arteries are needed. So their number is reduced to three- The coeliac artery, the superior mesenteric artery and inferior mesenteric artery.

There are initially four roots of ventral splanchnic arteries connected by longitudinal anastomoses. The first three roots form the left gastric, splenic and common hepatic arteries and the fourth root forms the superior mesenteric artery. Usually the part of second and third root proximal to anastomosis disappears. The anastomosis between the third and the fourth root also disappears.

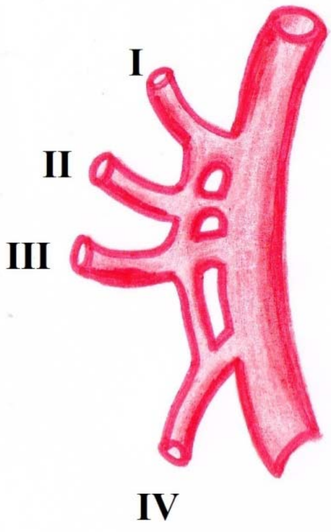
This leads to origin of the left gastric artery, splenic artery, common hepatic artery from coeliac artery, which is formed from the first root. If there occurs any variation in this process like, the part that normally disappears does not do so, or the part that usually persists disappears, this leads to variation in the branching pattern of coeliac artery. This explains the reason for displacement of any of the classic branches of coeliac artery to superior mesenteric artery (usually common hepatic artery) or its branches directly arising from the aorta.

As the organs descend into the abdomen, origin of the arteries supplying them also descend by differential growth. This descent transfers the origin of coeliac artery from seventh cervical segment to twelfth thoracic segment. This explains the inconsistent position of coeliac artery in relation to median arcuate ligament and its compression with the resultant syndrome.

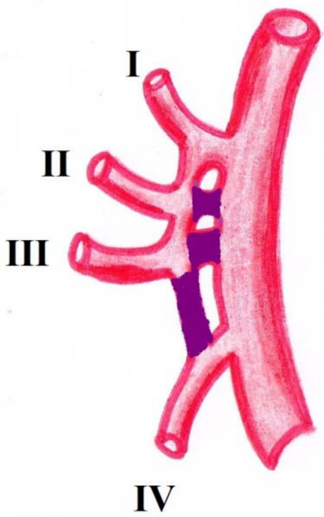
Diagram showing the segmental and intersegmental branches of abdominal aorta. Note the dorsal and ventral longitudinal anastomoses in relation to the gut tube.

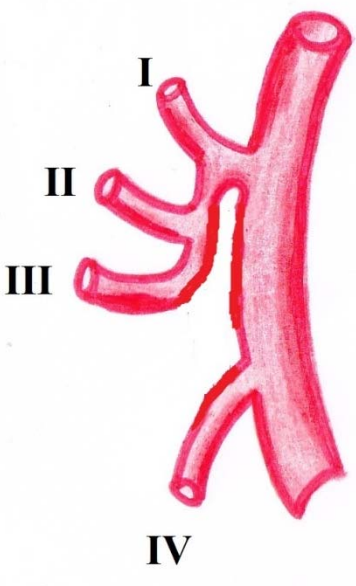


The four roots of ventral splanchnic arteries connected by longitudinal anastomosis

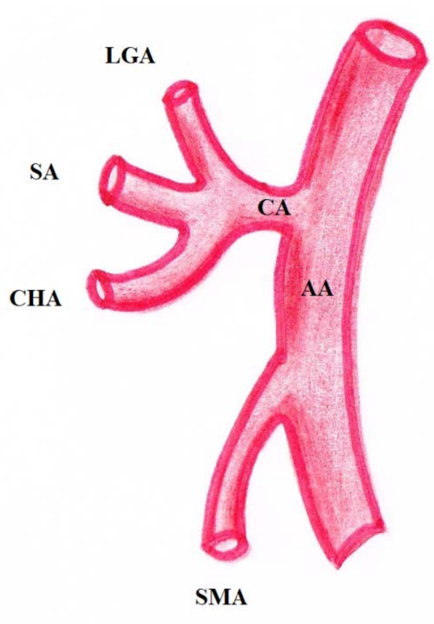


Parts of II & III roots proximal to anastomosis and anastomosis between III & IV roots disappear

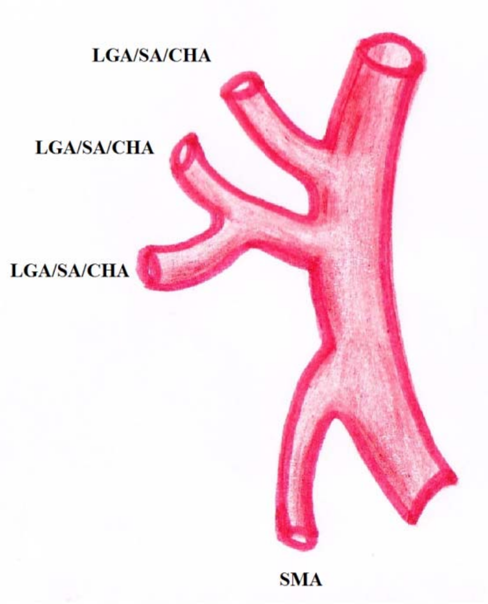




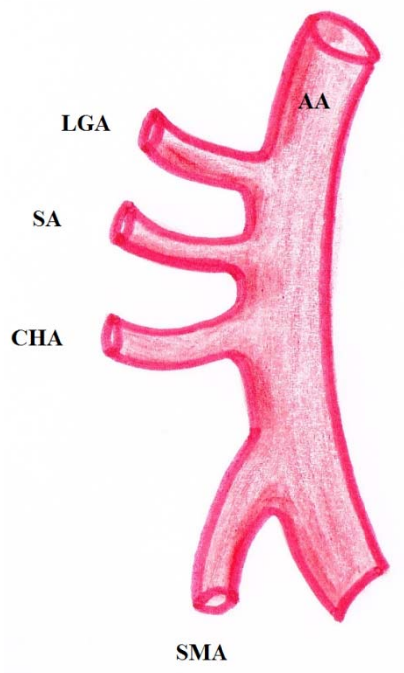
Normal Branching Pattern
Complete coeliac artery



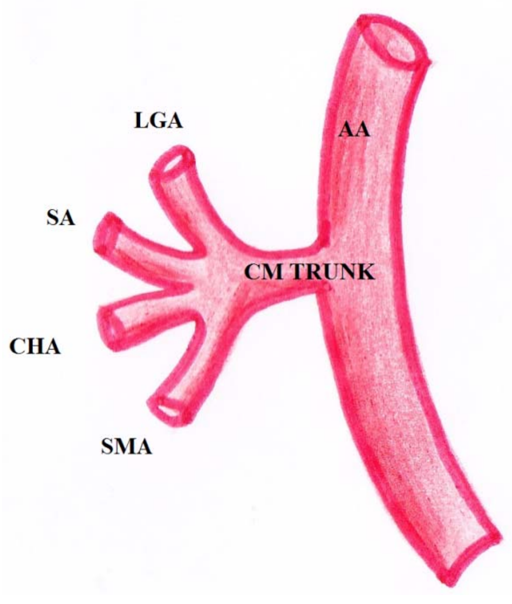
Incomplete coeliac artery



Absent coeliac artery



Coeliaco mesenteric trunk



Materials and Methods

MATERIALS AND METHODS

Study material

1. 50 embalmed adult human cadavers
2. 25 adult CT coeliac angiograms

Method of study

1. Conventional dissection method
2. Radiological study

Specimen collection

1. Embalmed adult human cadavers allotted for the routine academic dissection to the first year MBBS and BDS students at the Institute of Anatomy, Madras Medical College, Chennai.

2. 25 adult CT coeliac angiograms were collected irrespective of the patient particulars from the Barnard Institute of Radiology, Rajiv Gandhi Government General Hospital, Chennai.

Conventional Dissection Method:

The skin incision and the dissection of the layers of the anterior abdominal wall was done as per Cunningham's manual and the peritoneum was reflected. The greater omentum was identified and lifted up. Its continuity with the stomach and transverse colon were noted. The arterial arcade formed by the gastro-epiploic arteries in the greater omentum were identified. Anterior layer of the greater omentum was cut 2-3cm inferior to the arteries and the lower part of the lesser sac was opened. The liver was pulled superiorly. Its inferior margin was tilted anteriorly and the lesser omentum was exposed. If the lesser omentum was not sufficiently exposed, the left lobe of the liver was cut to the left of, falciform ligament and fissure for ligamentum teres.

The attachment of the left lobe to the lesser omentum was also cut. The anterior layer of the lesser omentum was removed close to the lesser curvature of the stomach. The LGA present in the lesser omentum was traced. The RGA was traced to its origin from the PHA. The PHA and its branches, the RHA and LHA were exposed till they reach the porta hepatis. The remaining lesser omentum was removed leaving the vessels in place. The abdominal wall posterior to the lesser omentum and the lesser sac were examined. The lienorenal ligament posterior to the spleen was identified and the SA present in it was exposed. The stomach along with the RGA and epiploic vessels were cut to the left of the pylorus and the lesser sac was exposed. The peritoneum present in the posterior wall of lesser sac was removed. The CA was identified and the dense autonomic plexus surrounding it were removed to expose its branches.

All the branches derived from the CA namely the LHA, SA and CHA were carefully traced. Other additional significant branches were noted when encountered. Then the abdominal viscera were removed systematically according to Cunningham’s manual. The level of origin of CA and its relation to MAL were noted. Photographs were taken and recorded. The details about the CA of every specimen were recorded and analysed.

Radiological study:

25 adult CT coeliac angiograms were obtained from the archives of Barnard Institute of Radiology and the CA was studied.

Observation

OBSERVATION

LEVEL OF ORIGIN OF COELIAC ARTERY

Among 50 adult specimens the origin of CA was at the level of upper border of T_{12} in 5 specimens, at the lower border of T_{12} in 32 specimens, at the intervertebral disc between T_{12} and L_1 in 3 specimens and at the upper border of L_1 in 10 specimens

TABLE 1 : LEVEL OF ORIGIN OF CA

Level of origin of CA	Frequency	Percentage
Upper border of T_{12}	5	10%
Lower border of T_{12}	32	64%
Between T_{12} and L_1	3	6%
the upper border of L_1	10	20%

CHART 1 : LEVEL OF ORIGIN OF CA

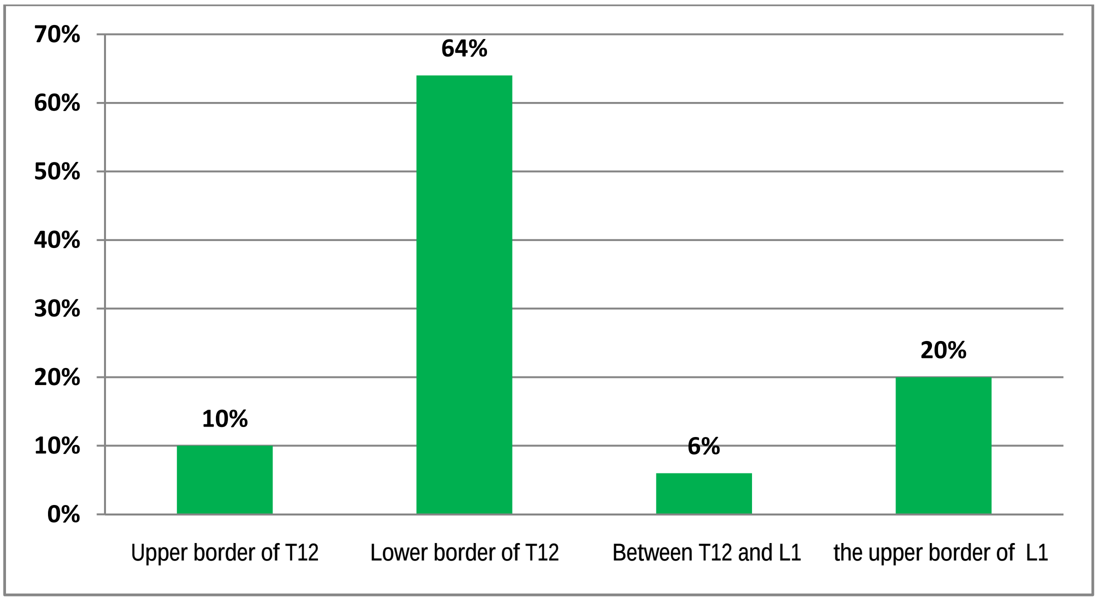


Fig.1 : Origin of coeliac artery above the level of median arcuate ligament

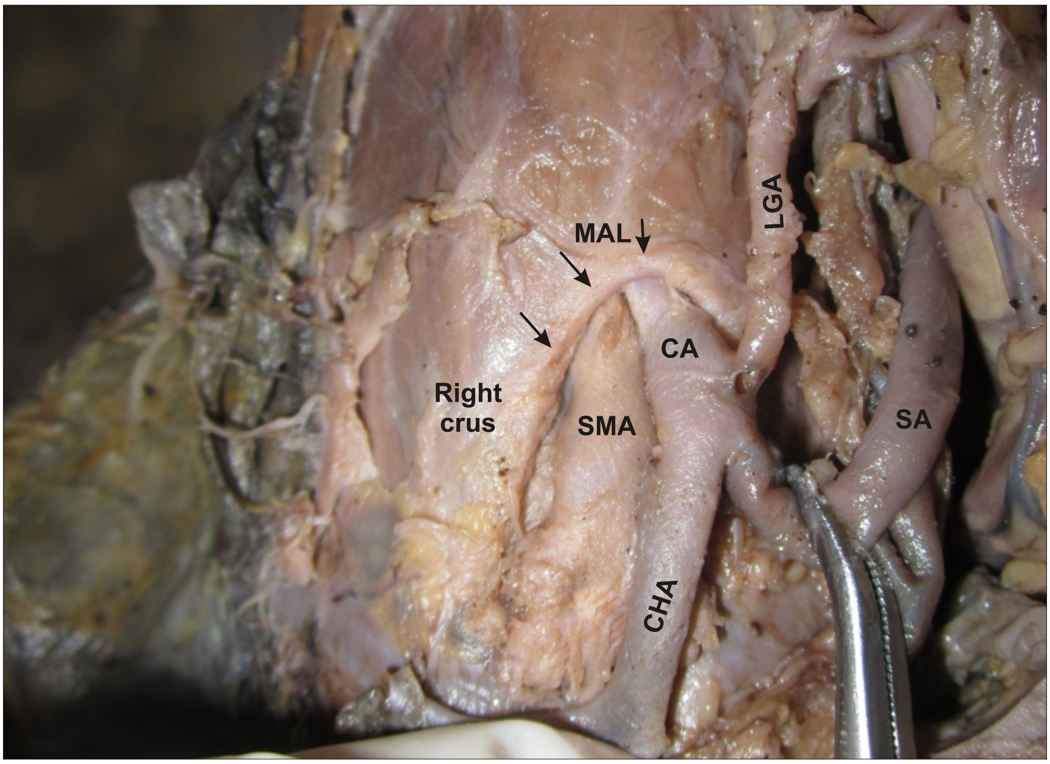
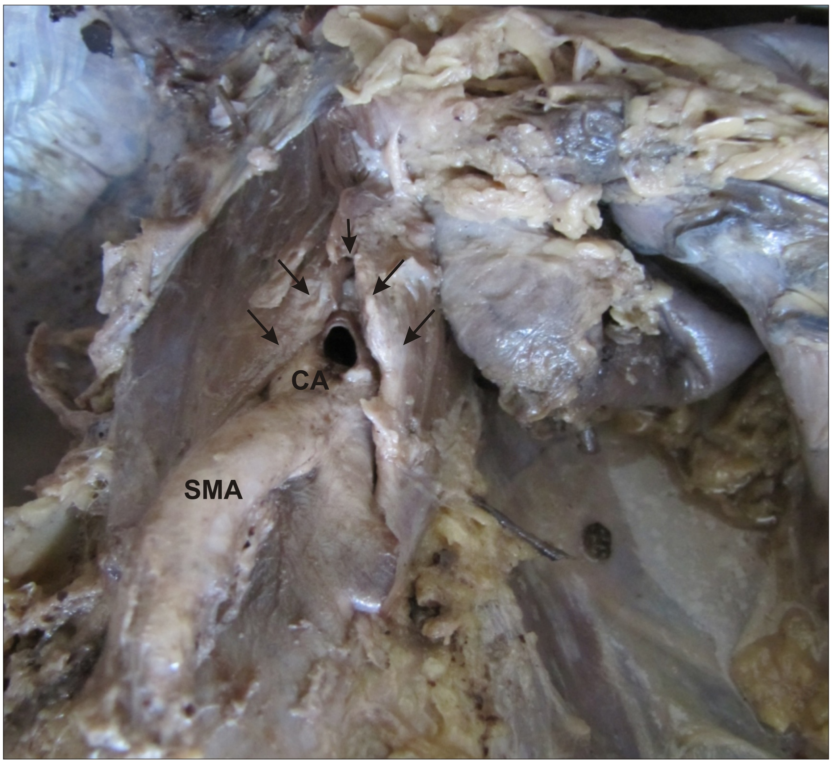


Fig. 2A. Origin of coeliac artery at the level of median arcuate ligament

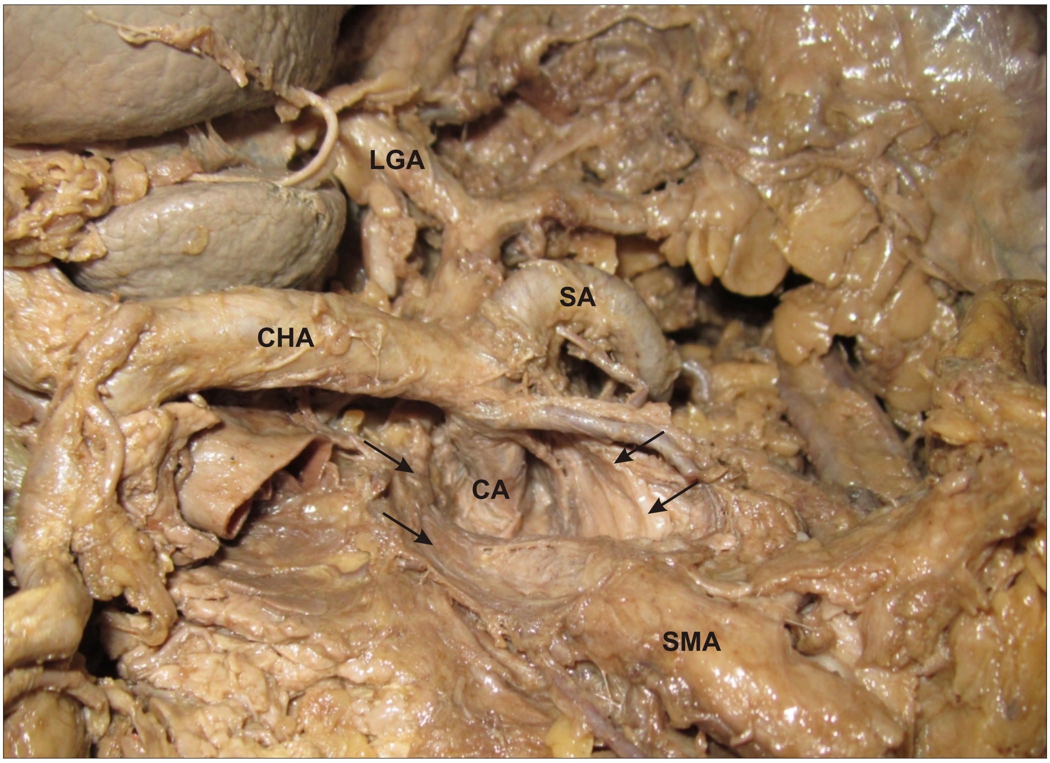
Arrow indicates MAL

Fig. 2B. Origin of coeliac artery at the level of median arcuate ligament



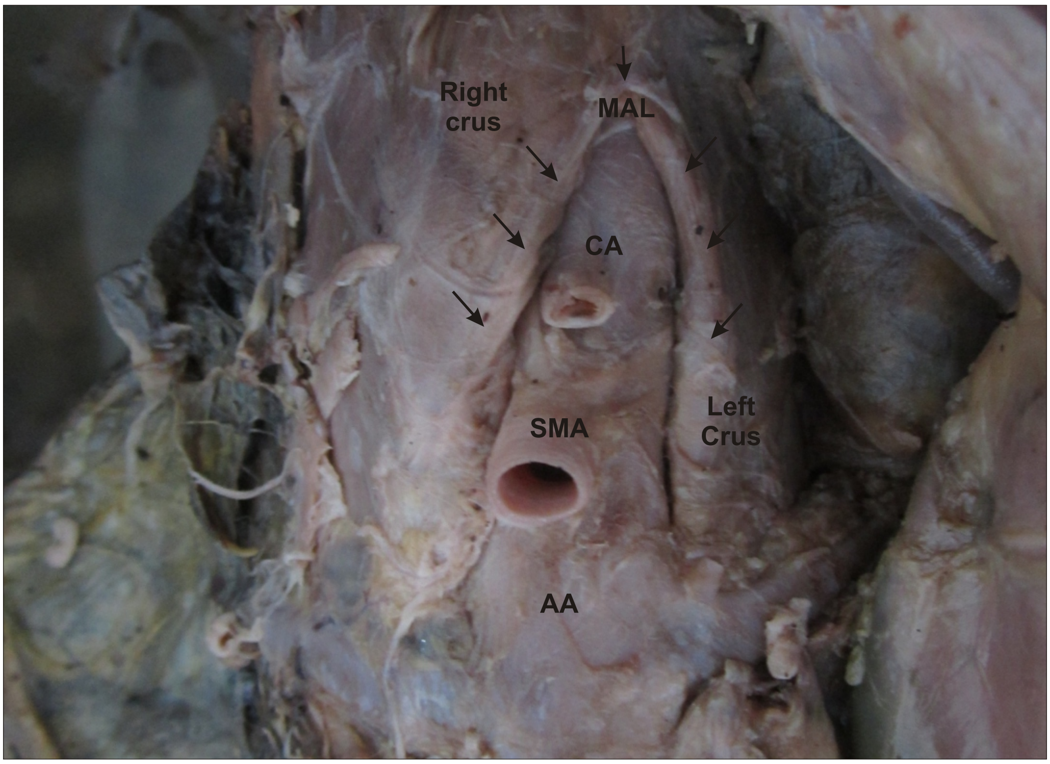
Arrow indicates MAL

Fig. 2C. Origin of coeliac artery at the level of median arcuate ligament



Arrow indicates MAL

Fig. 3 Origin of coeliac artery below the level of median arcuate ligament



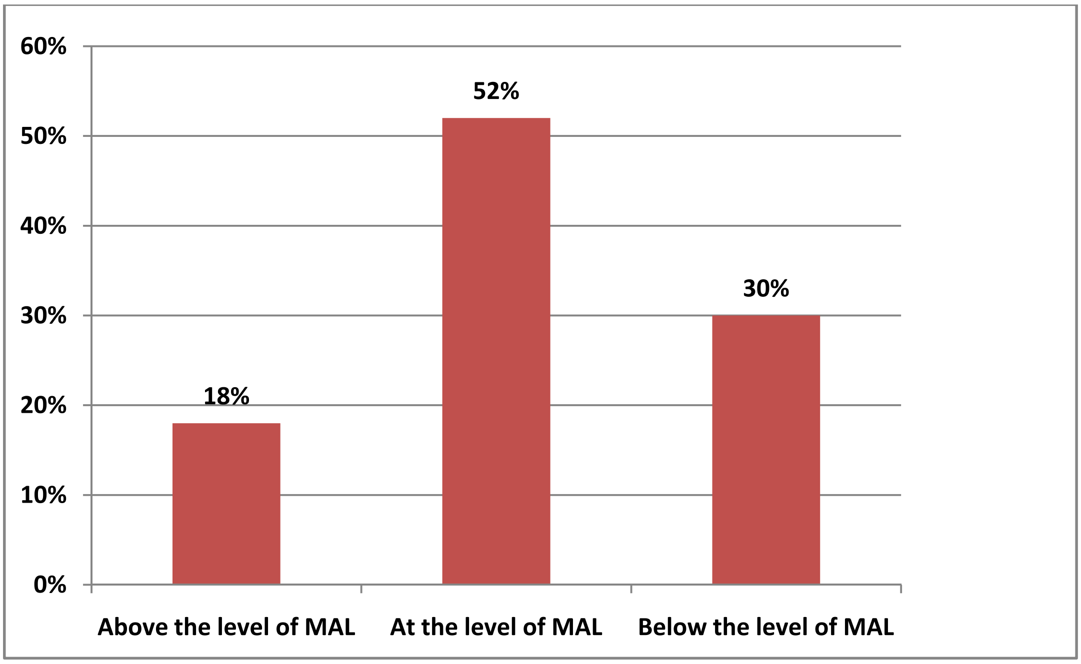
ORIGIN OF COELIAC ARTERY IN RELATION TO MEDIAN ARCUATE LIGAMENT OF DIAPHRAGM

Among the 50 adult specimens the origin of CA was located above the MAL in 9 specimens (Fig1), at the level of MAL in 26 specimens (Fig2A,B&C) and below the level of MAL in 15 specimens (Fig3).

TABLE 2 : ORIGIN OF CA IN RELATION TO MAL

Origin of CA in relation to MAL	Frequency	Percentage
Above the level of MAL	9	18%
At the level of MAL	26	52%
Below the level of MAL	15	30%

CHART 2 : ORIGIN OF CA IN RELATION TO MAL



LENGTH OF CA FROM ITS ORIGIN TO EMERGENCE OF FIRST BRANCH

Length of CA was measured from the point of origin to the point of emergence of first branch. The following were observed.

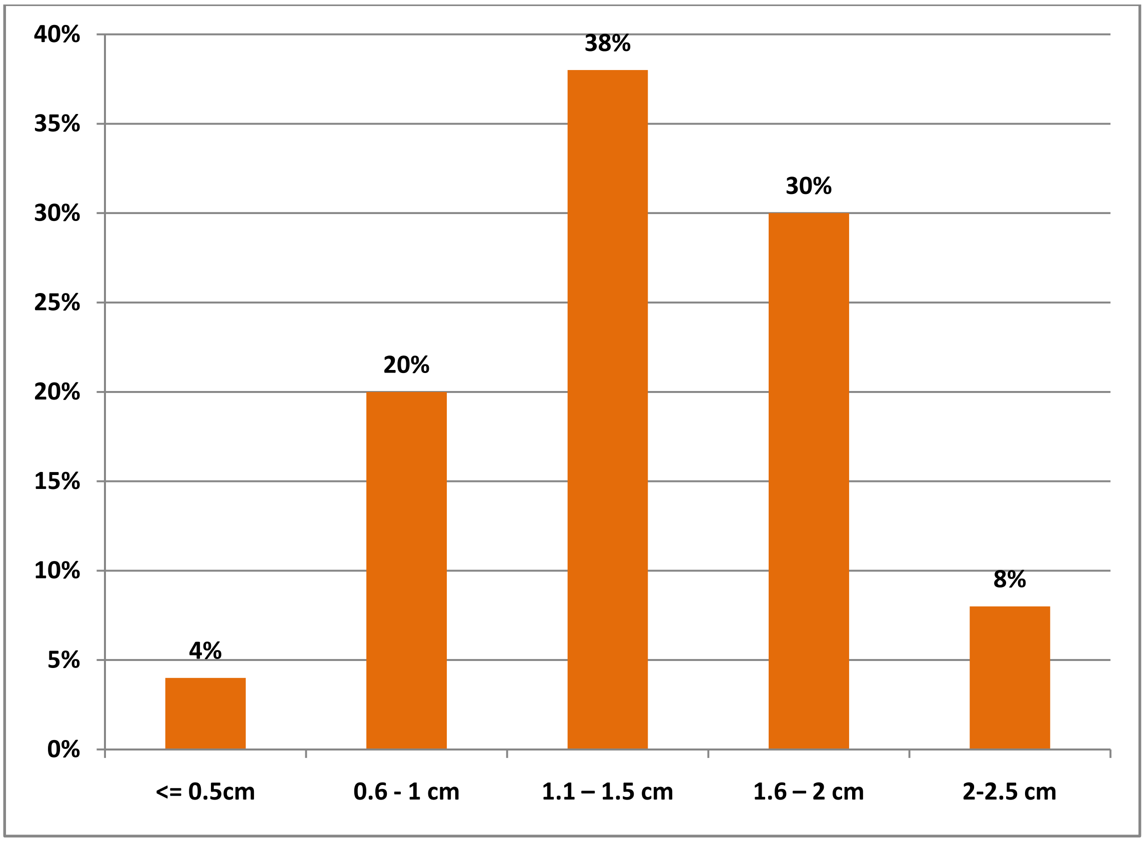
TABLE 3 : LENGTH OF CA FROM ITS ORIGIN TO EMEREGENCE OF FIRST BRANCH

Measurements	Length in cm
Minimum length	0.4
Maximum length	2.4
Mean length	1.37

TABLE 4 : LENGTH OF CA

Length of CA	Frequency	Percentage
<= 0.5cm	2	4%
0.6 - 1 cm	10	20%
1.1 – 1.5 cm	19	38%
1.6 – 2 cm	15	30%
2.1 – 2.5 cm	4	8%

CHART 3 : LENGTH OF CA



TYPE OF CA

Among the 50 specimens CA was complete with all the 3 classic branches (LGA, SA, CHA) arising from it in 39 specimens (Fig4&5) and had aberrant branches in addition to classic branches in 11 specimens (Fig7&8).

In dissection done on a three month old infant in the Institute Of Anatomy, Madras Medical College, the CA was complete. The LGA originated first followed by bifurcation into CHA and SA (Fig6).

Fig. 4. Coeliac artery- complete type, non classical trifurcation

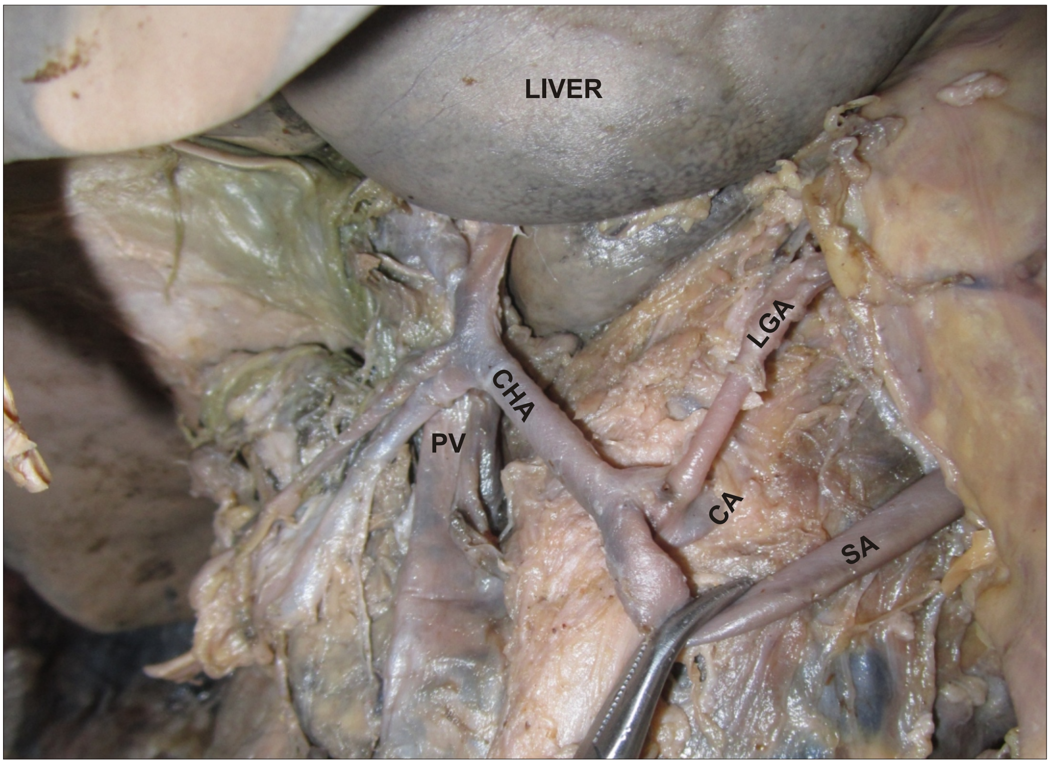


Fig. 5. Coeliac Artery- complete type, classical trifurcation

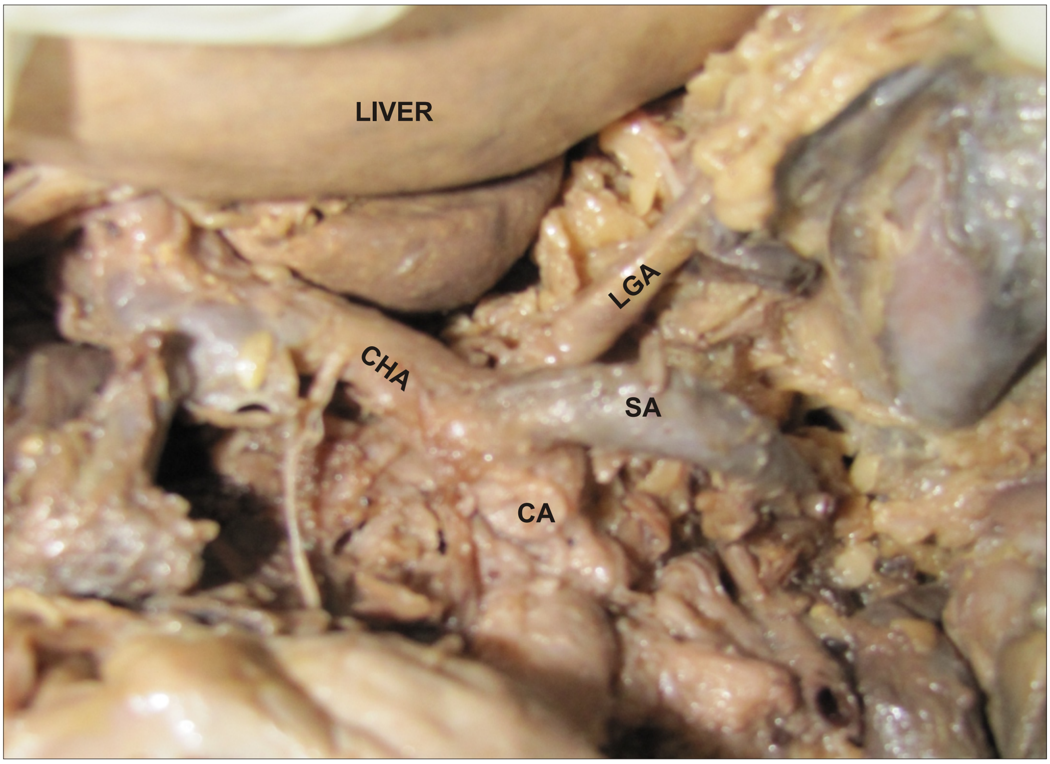


Fig. 6. Infant dissection - Coeliac artery, complete type, non classical trifurcation

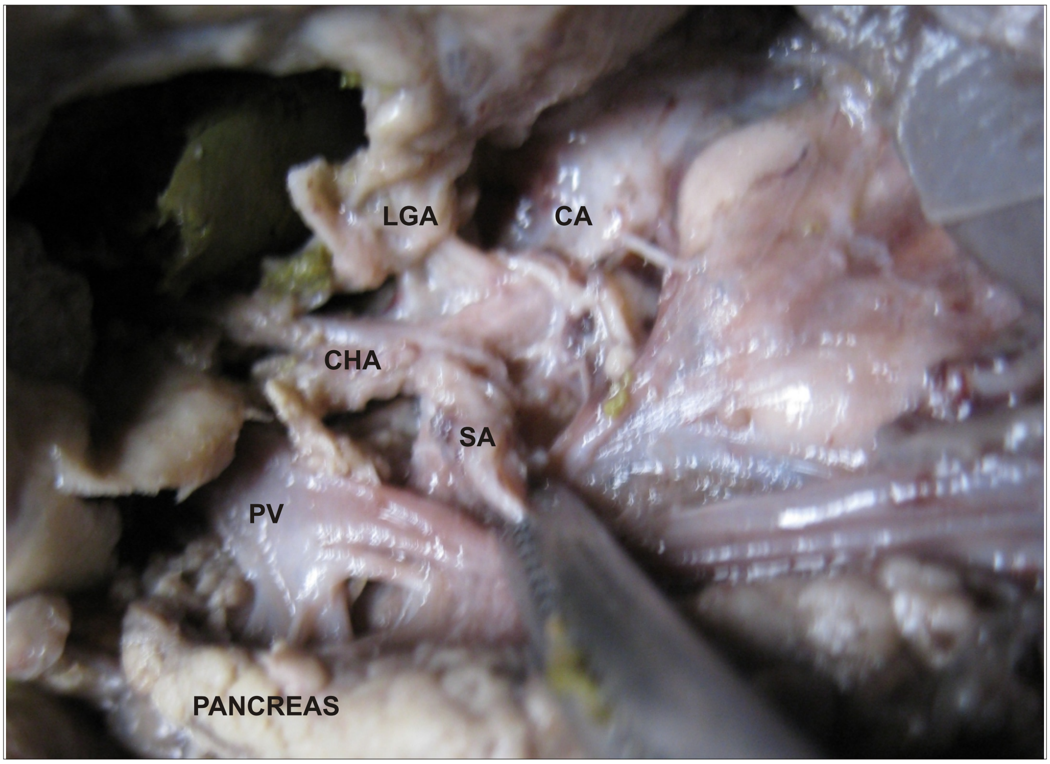


Fig. 7. Coeliac artery with aberrant branches- the RIPA and LIPA

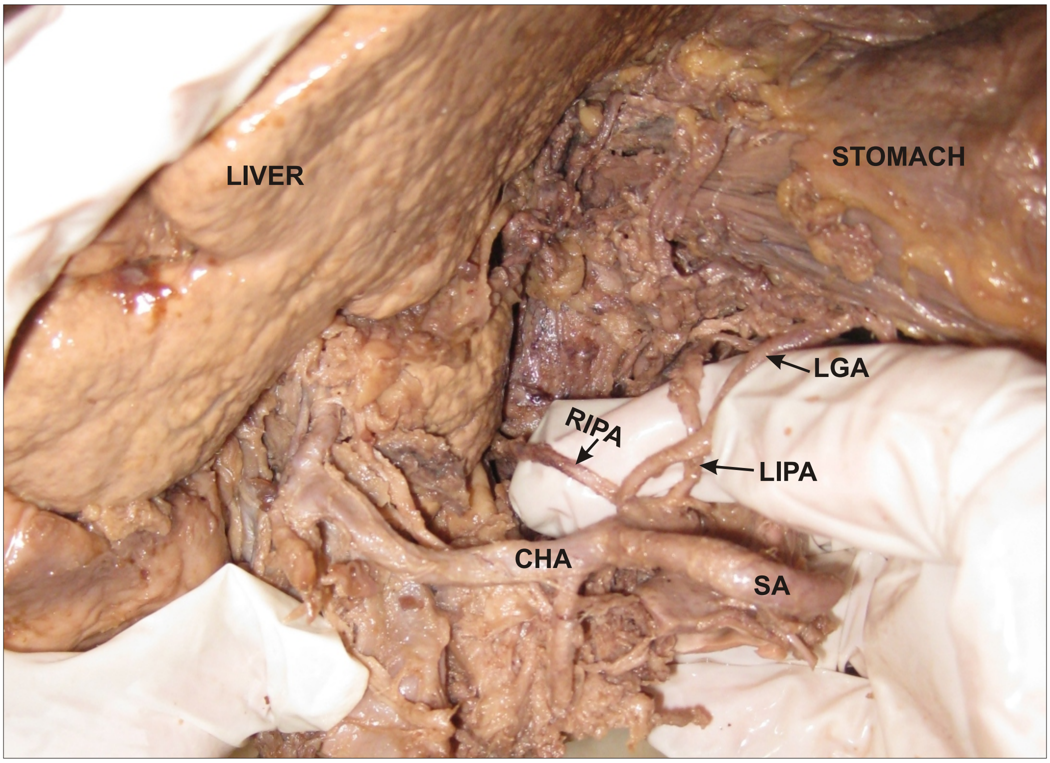


TABLE 5 : TYPE OF CA

Type of CA	Frequency	Percentage
Complete	39	78%
Incomplete	-	0%
Absent	-	0%
Coeliacomesentric trunk	-	0%
Aberrant branches	11	22%

CHART 4 : TYPE OF CA

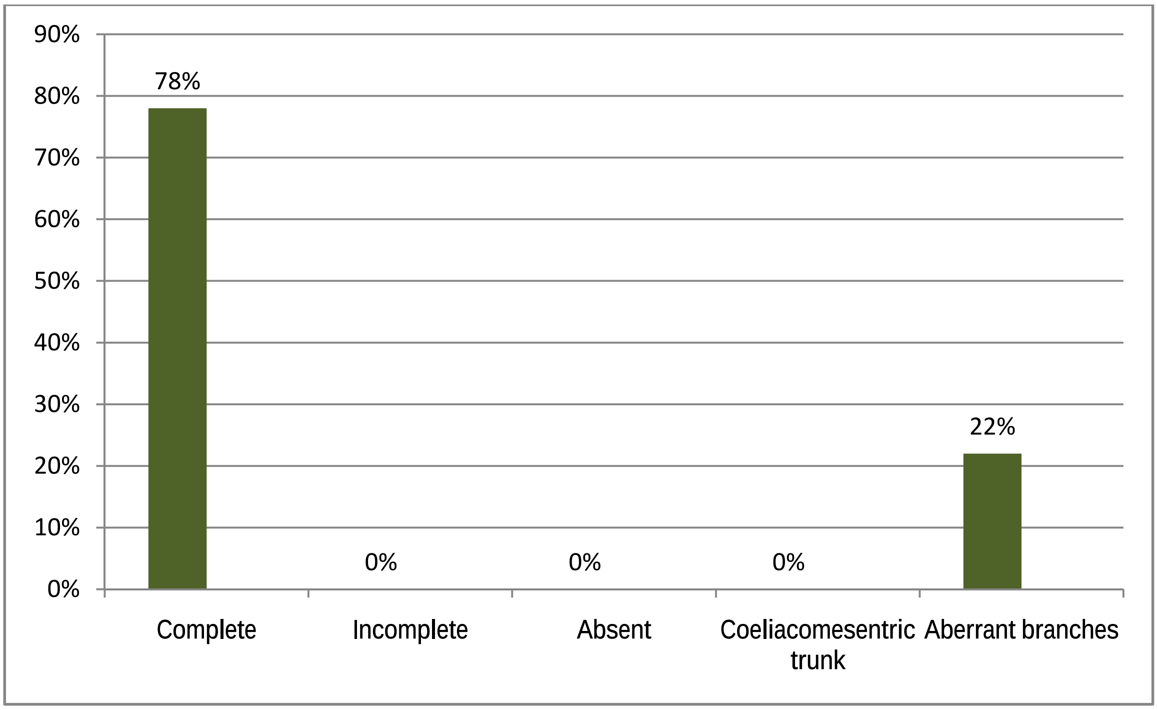


Fig. 8. Coeliac artery with aberrant branch- dorsal pancreatic artery

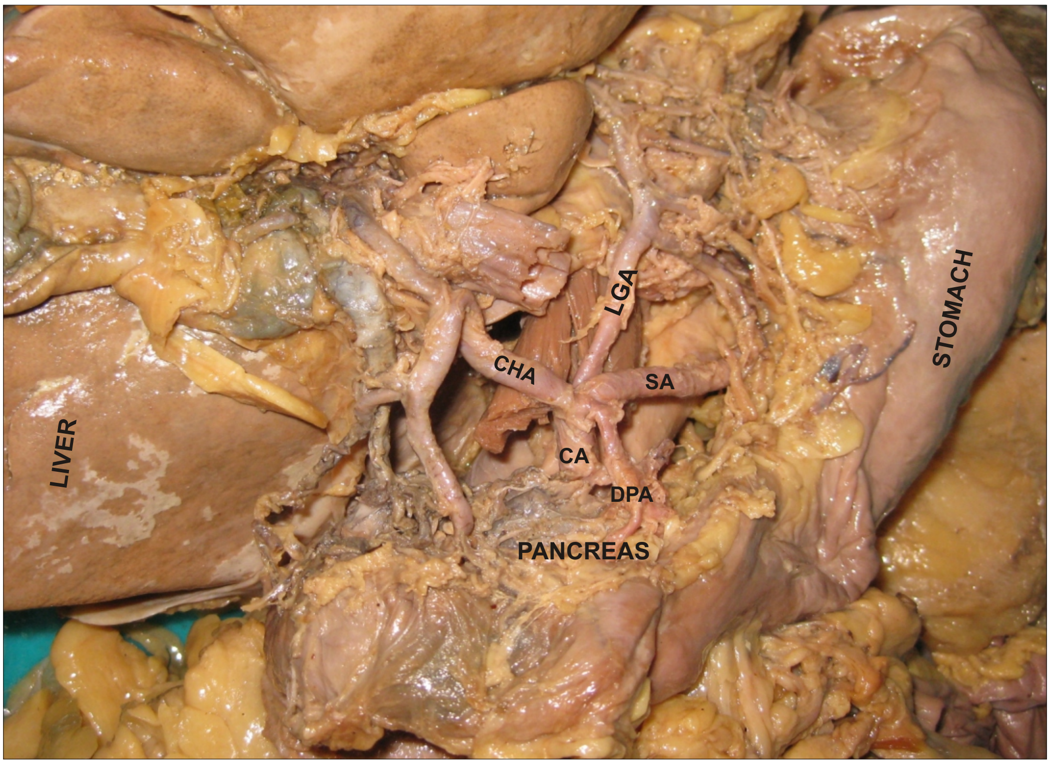
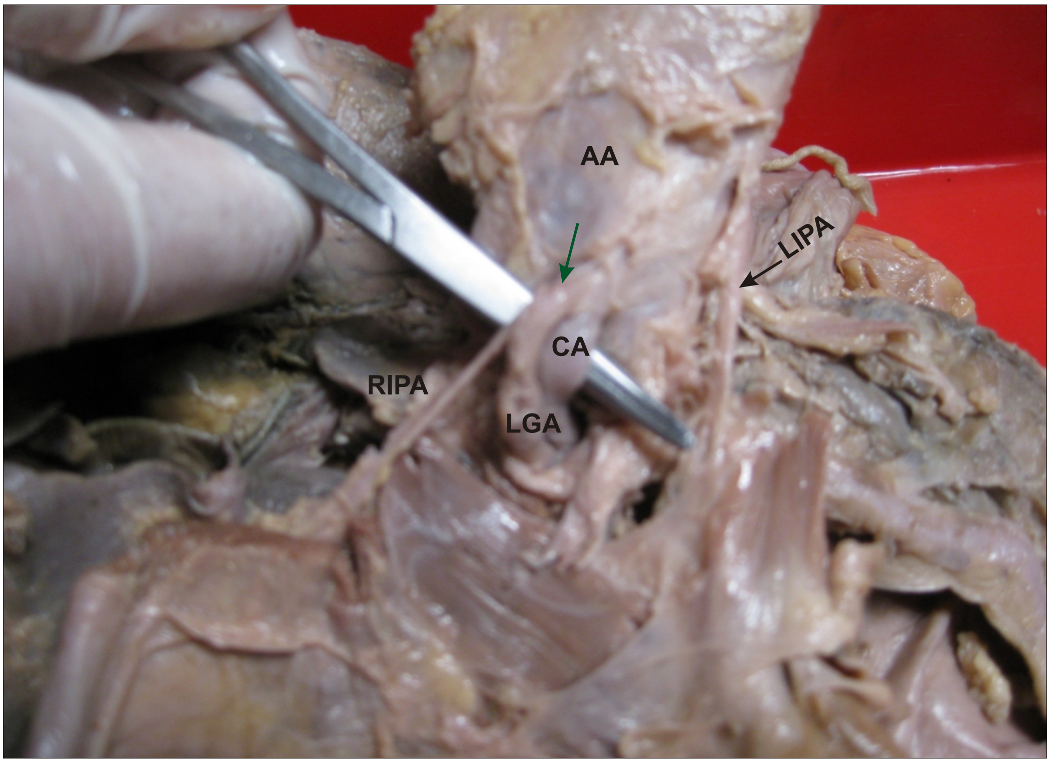


Fig. 9. Gastrophrenic trunk from coeliac artery - RIPA and LGA.



↓ **Arrow indicates gastrophrenic trunk**

Branching pattern of CA

In 34 specimens the CA bifurcated into hepato splenic trunk with the LGA arising separately proximal to the bifurcation(Fig4). In 5 specimens the CA trifurcated classically(all the branches arising from CA at the same point) (Fig5). In 2 specimens CA quadrifurcated into LGA, SA, CHA and DPA(Fig8). In 1 specimen CA gave rise to a gastrophrenic trunk and hepatosplenic trunk(Fig9).

In 3 specimens both the LIPA & RIPA arose from CA separately proximal to origin of LGA(Fig7).

In 5 specimens the RIPA arose from CA proximal to the emergence of its three branches namely LGA, SA, CHA

TABLE 6 : NUMBER OF BRANCHES OF CA

Number of branches from CA	Frequency	Percentage
2	-	0%
3	39	78%
4	8	16%
5	3	6%

Fig. 10.Left gastric artery arising from coeliac artery

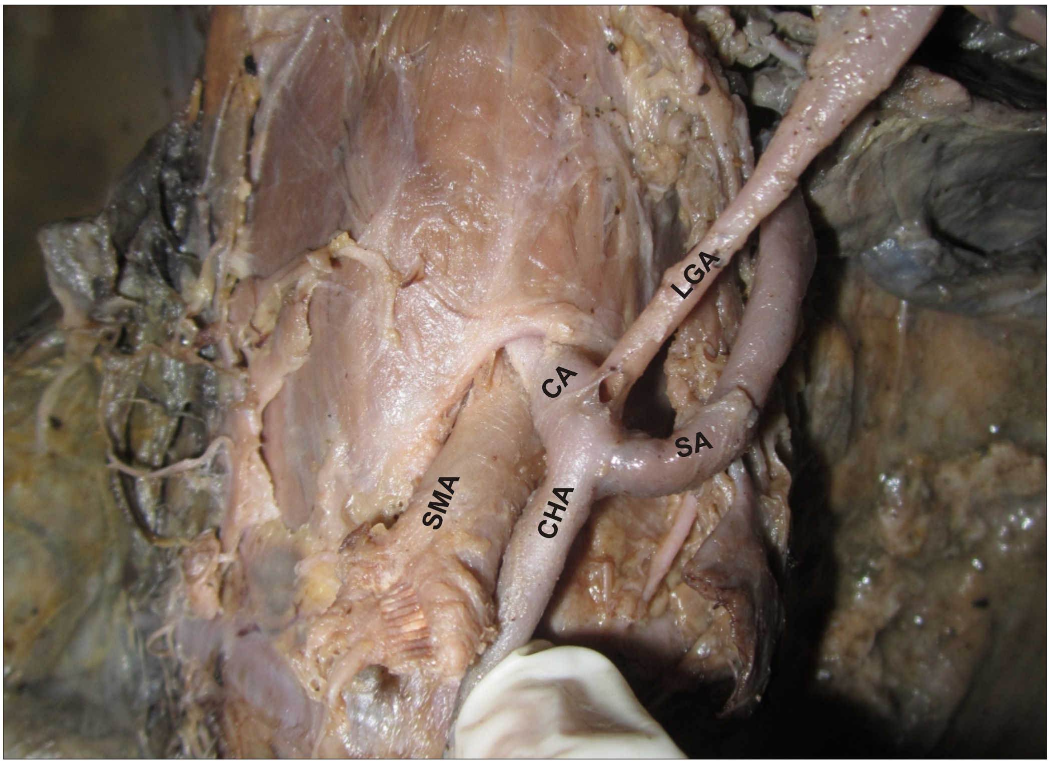


Fig. 11. Splenic artery arising from coeliac artery

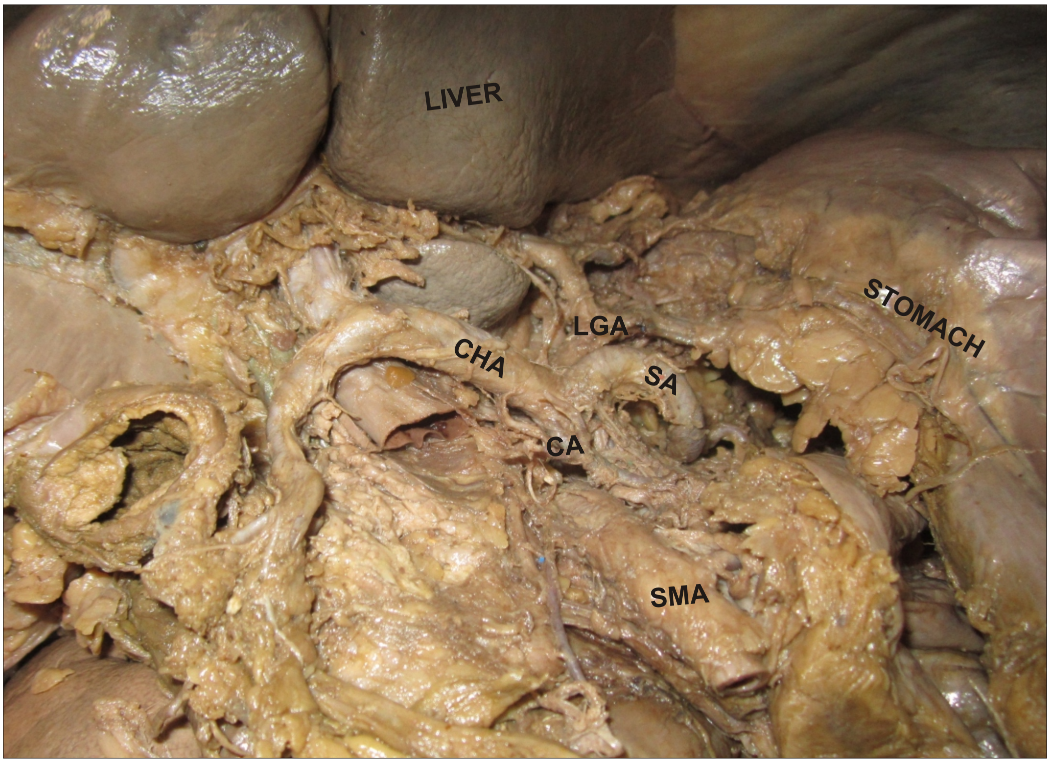


Fig. 12. Common hepatic artery arising from coeliac artery

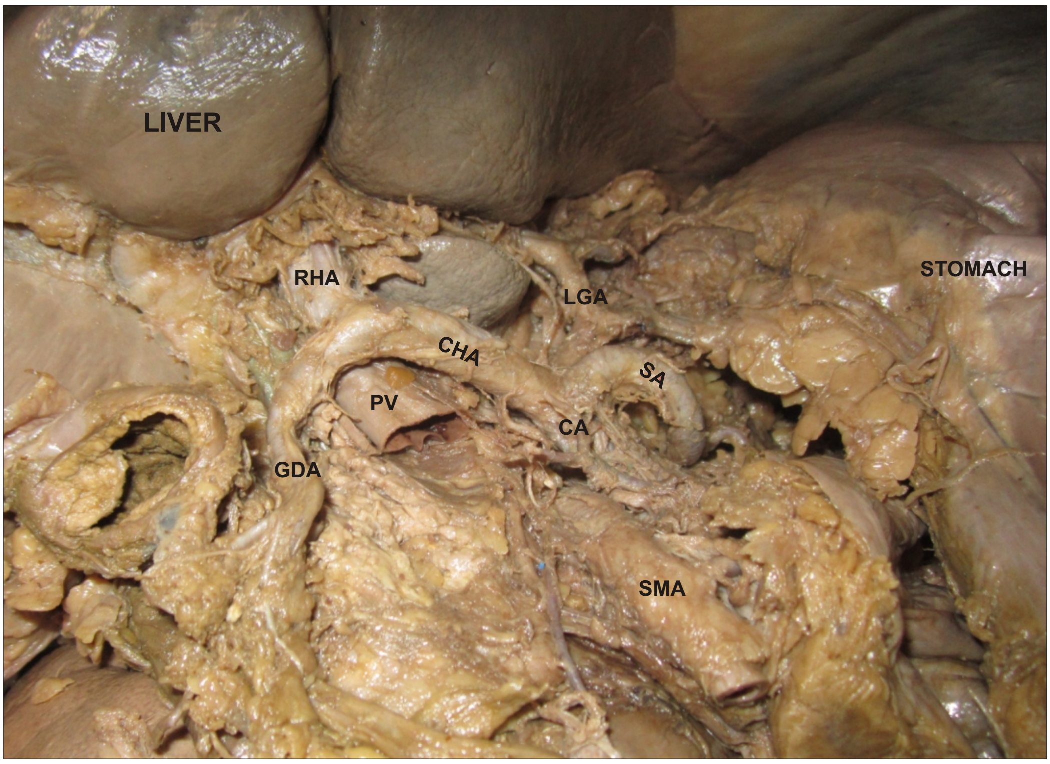


Fig. 13. Left hepatic artery arising from proper hepatic artery

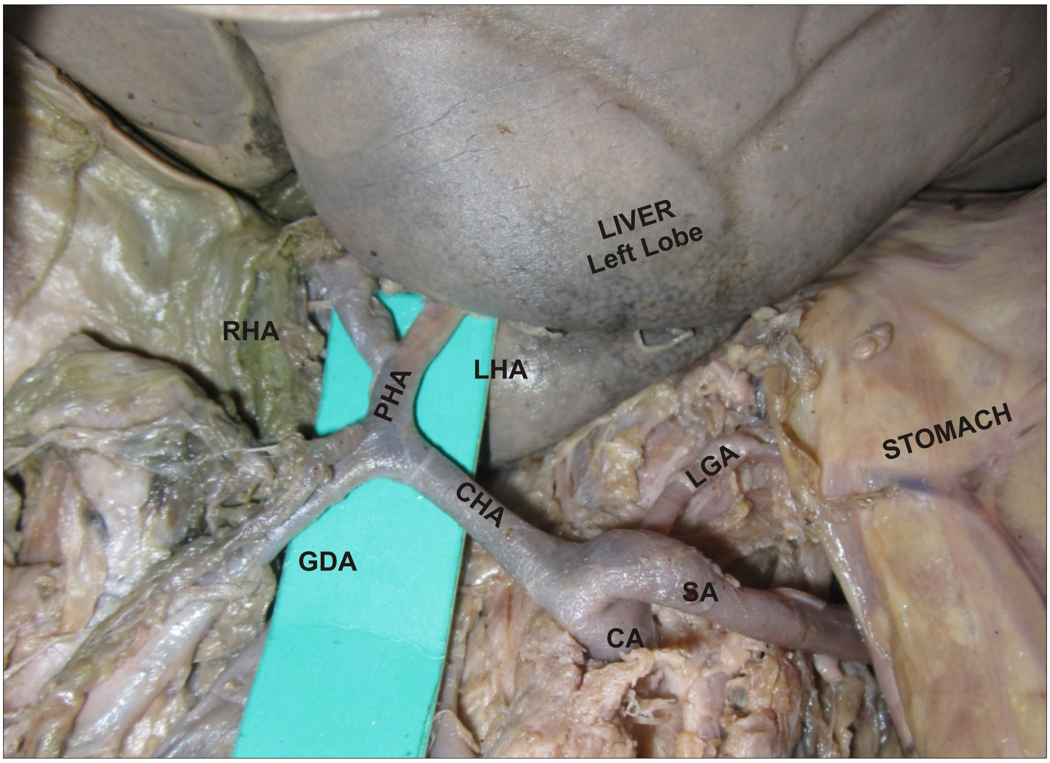
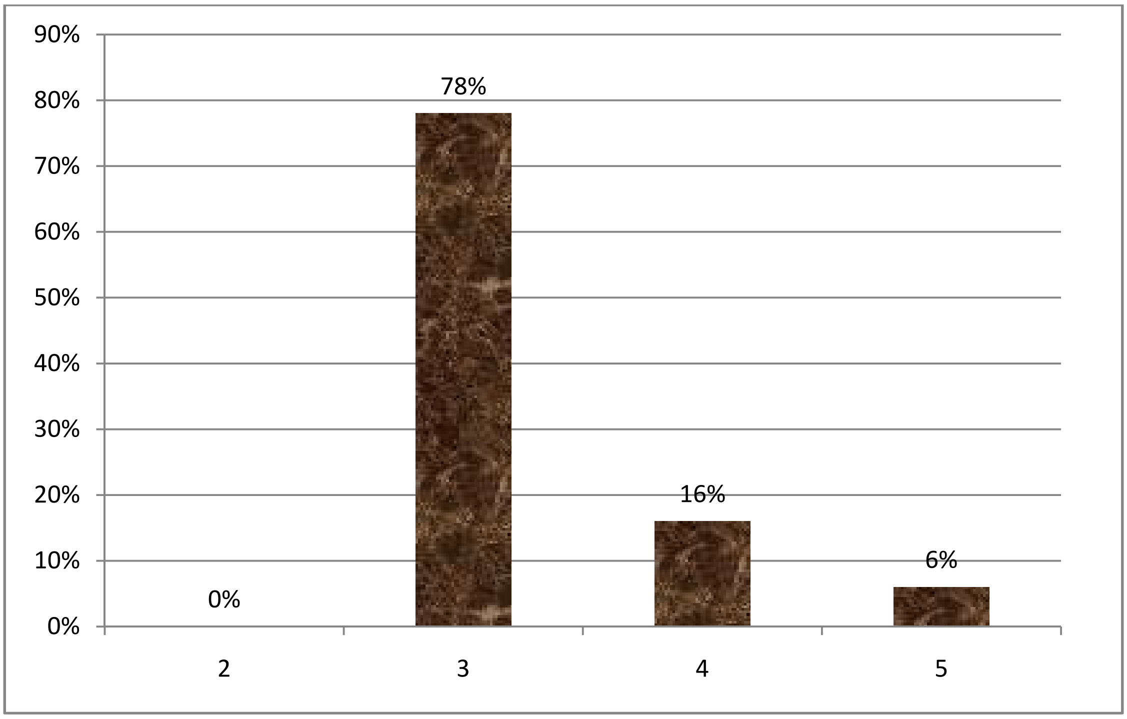


CHART 5 : NUMBER OF BRANCHES OF CA



BRANCHES OF CA

- **LGA**
    - In all the 50 specimens the LGA arose from CA (Fig10).

- **SA**
    - In all the 50 specimens the SA arose from the CA (Fig11).

- **CHA**
    - In all the 50 specimens the CHA arose from the CA (Fig12).

Fig. 14.Replaced left hepatic artery arising from left gastric artery

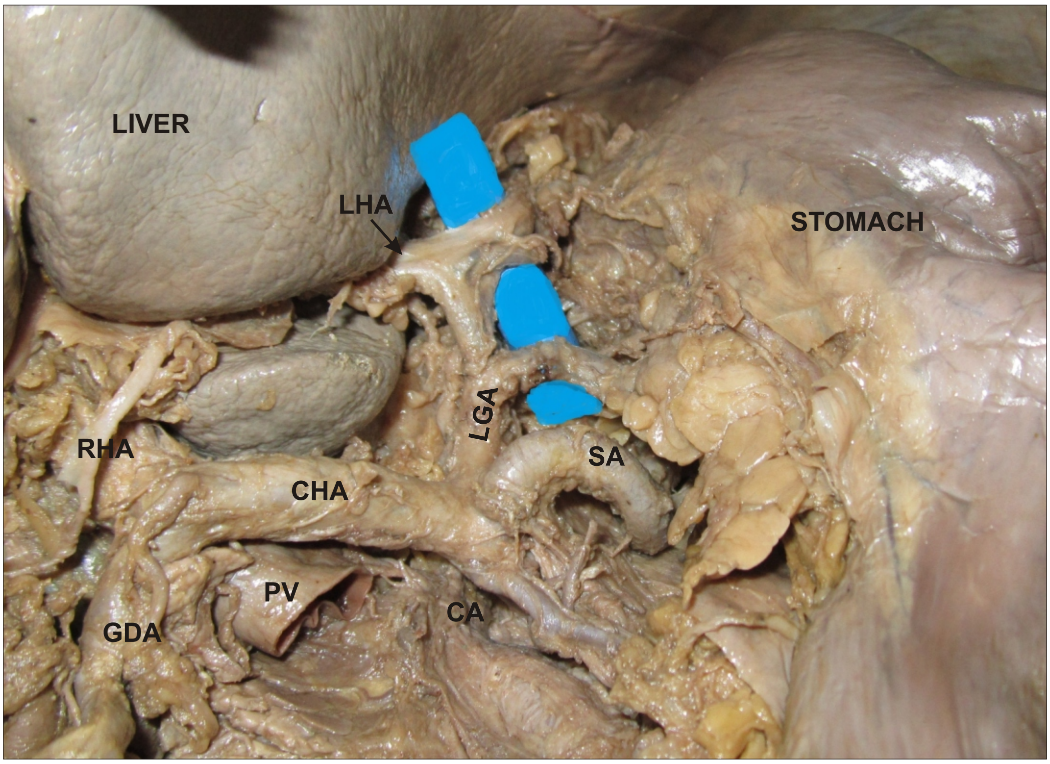


Fig. 15. Accessory left hepatic artery arising from left gastric artery

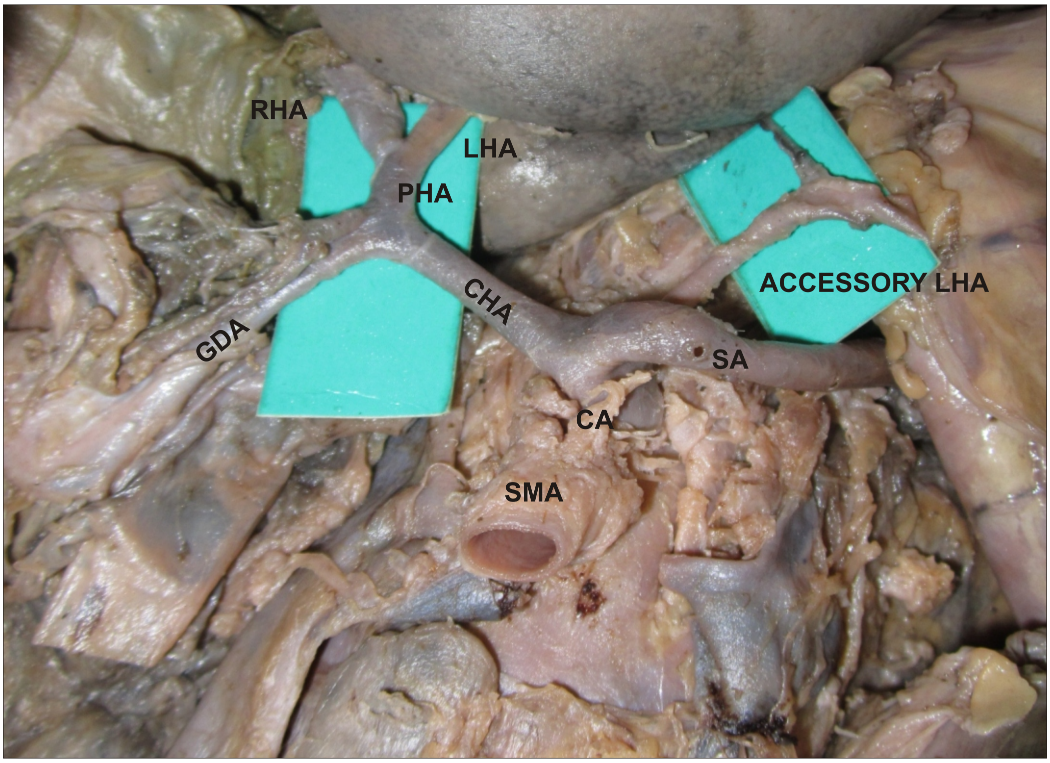


Fig. 16. Left hepatic artery arising from common hepatic artery

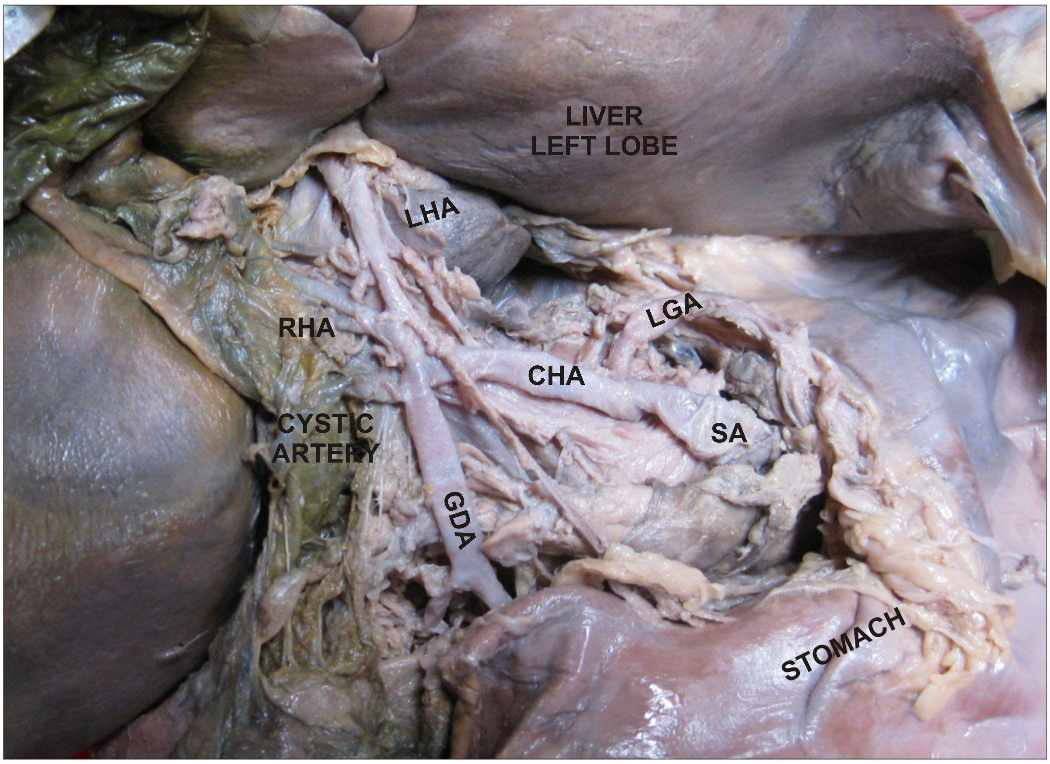
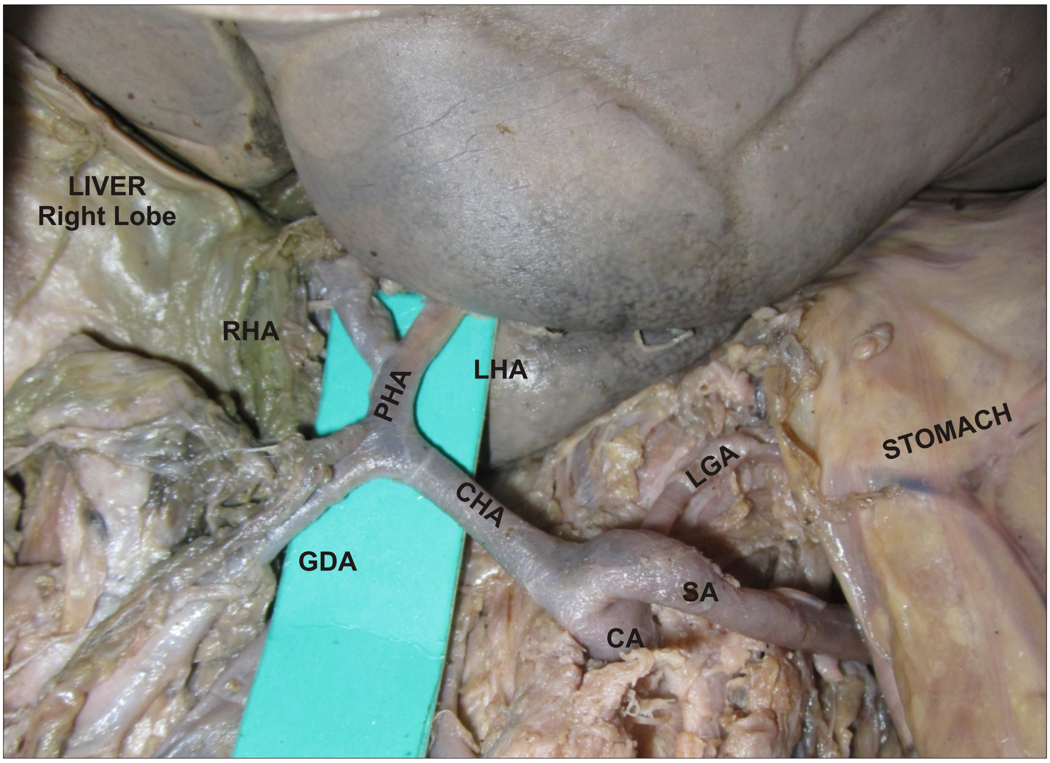


Fig. 17. Right hepatic artery arising from proper hepatic artery



BRANCHES OF CHA

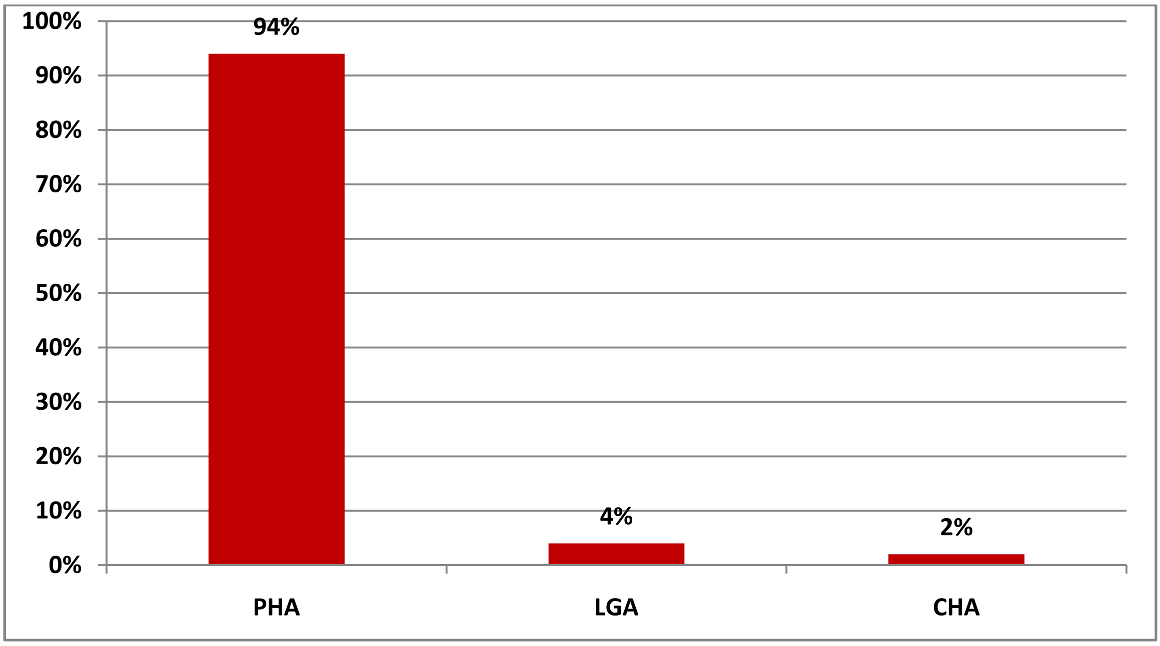
LHA

Among 50 specimens the LHA originated from PHA in 47 specimens (Fig13), from LGA as replaced LHA in 2 specimens (Fig14) and from CHA in 1 specimen (Fig16). Accessory LHA was observed in 2 specimens(Fig15).

TABLE 7 : SOURCE OF LHA

Source of LHA	Frequency	Percentage
PHA	47	94%
LGA	2	4%
CHA	1	2%

CHART 6 : SOURCE OF LHA



RHA

In 49 specimens RHA arose from PHA (Fig17). In the remaining 1 specimen it originated from CHA (Fig18).

TABLE 8 : SOURCE OF RHA

Source of RHA	Frequency	Percentage
PHA	49	98%
CHA	1	2%

CHART 7 : SOURCE OF RHA

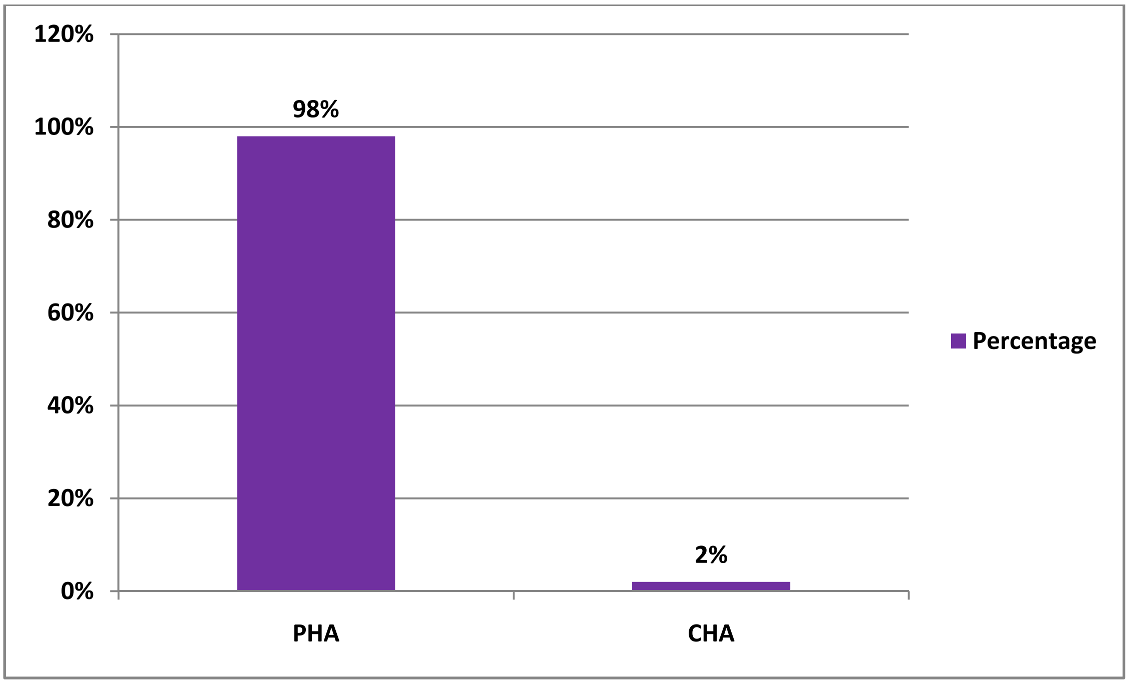


Fig.18.Right hepatic artery arising from common hepatic artery

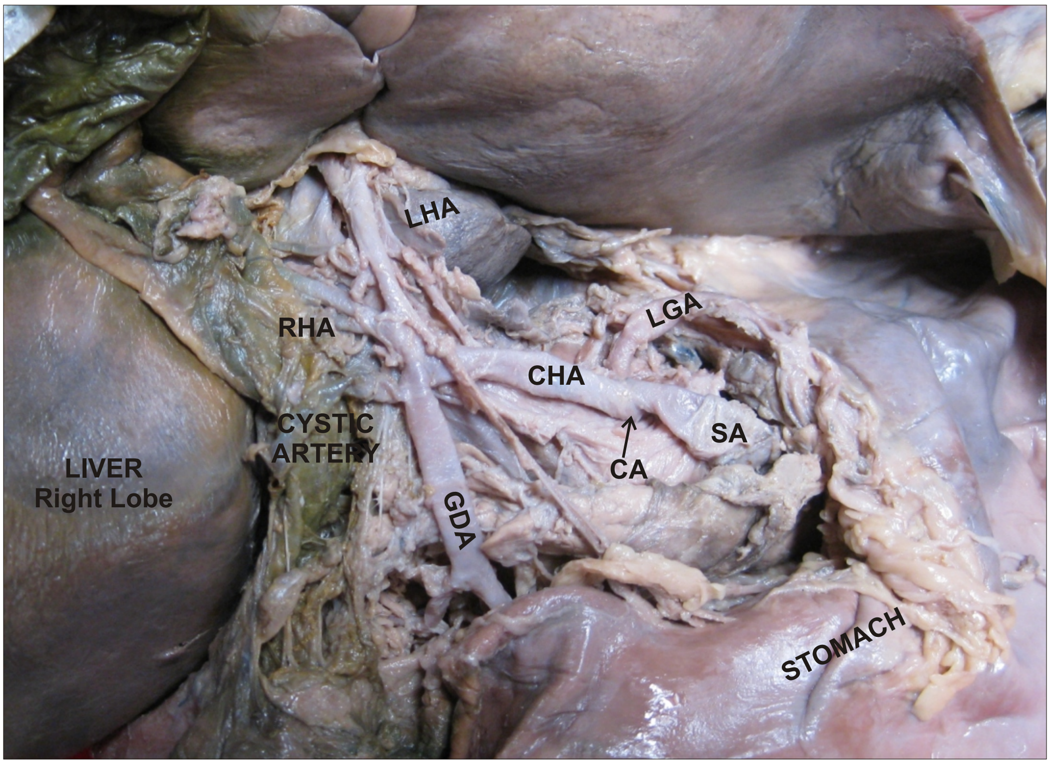
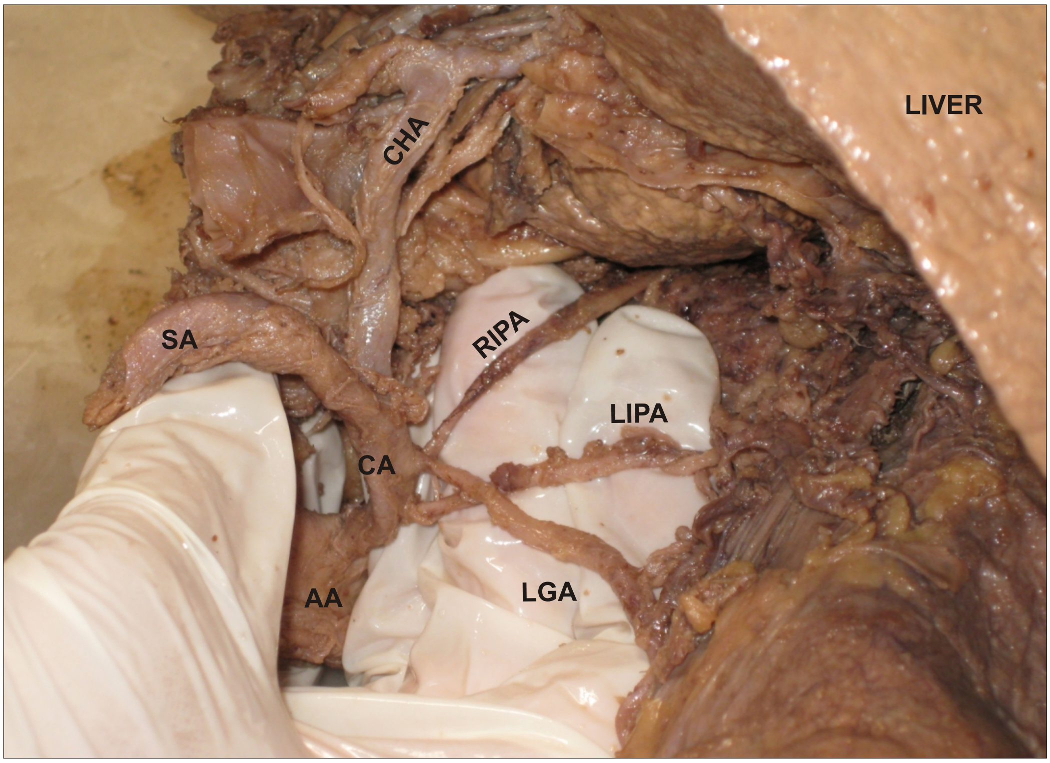


Fig.19.RIPA and LIPA from coeliac artery as independent branches



ABERRANT BRANCHES

LIPA

In 47 specimens the LIPA arose from AA. In 3 specimens it arose from CA (Fig19).

TABLE 9 : SOURCE OF LIPA

Source of LIPA	Frequency	Percentage
CA	3	6%
Aorta	47	94%

CHART 8 : SOURCE OF LIPA

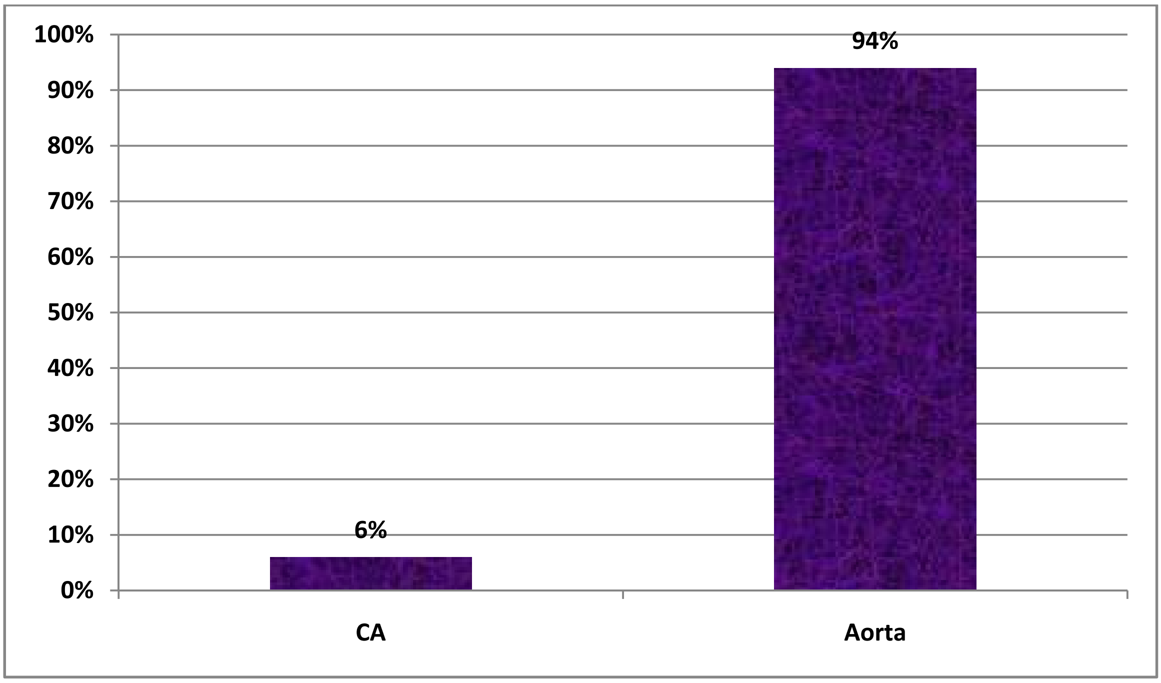


Fig. 20.RIPA from coeliac artery and LIPA from aorta

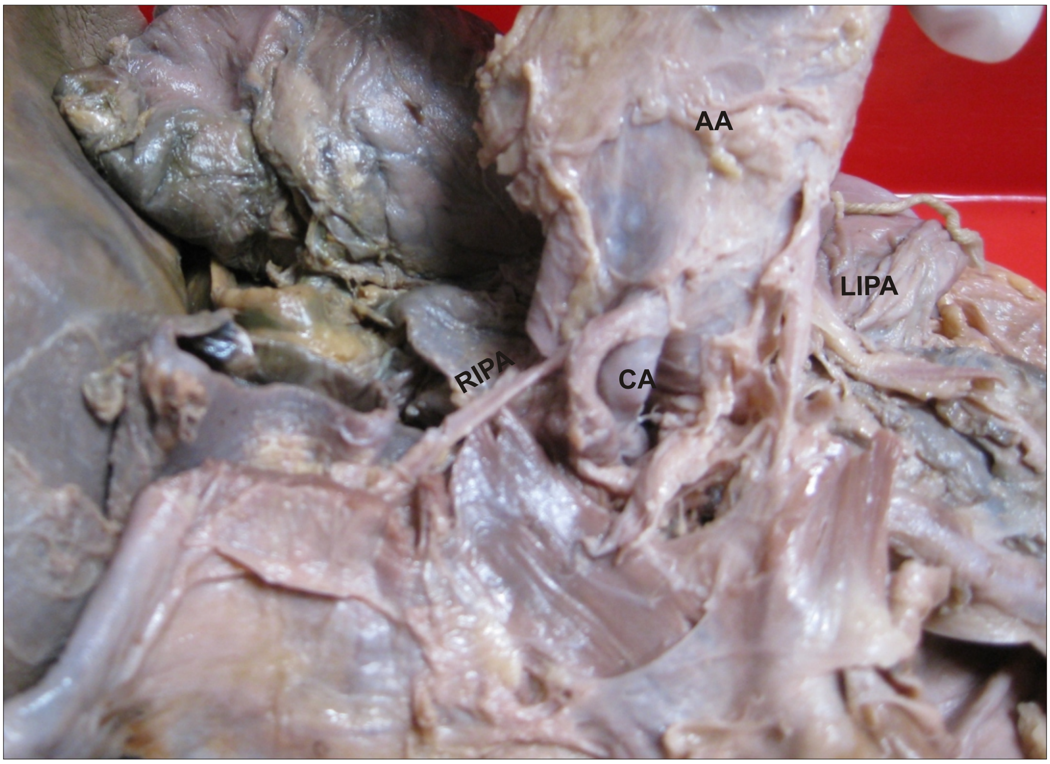
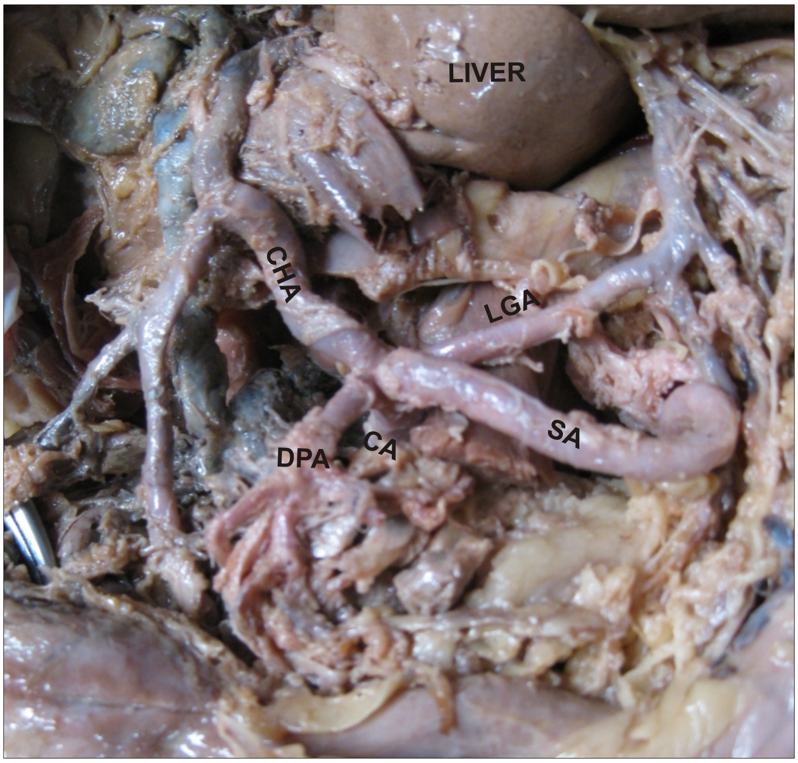


Fig. 21A. Dorsal pancreatic artery arising from coeliac artery



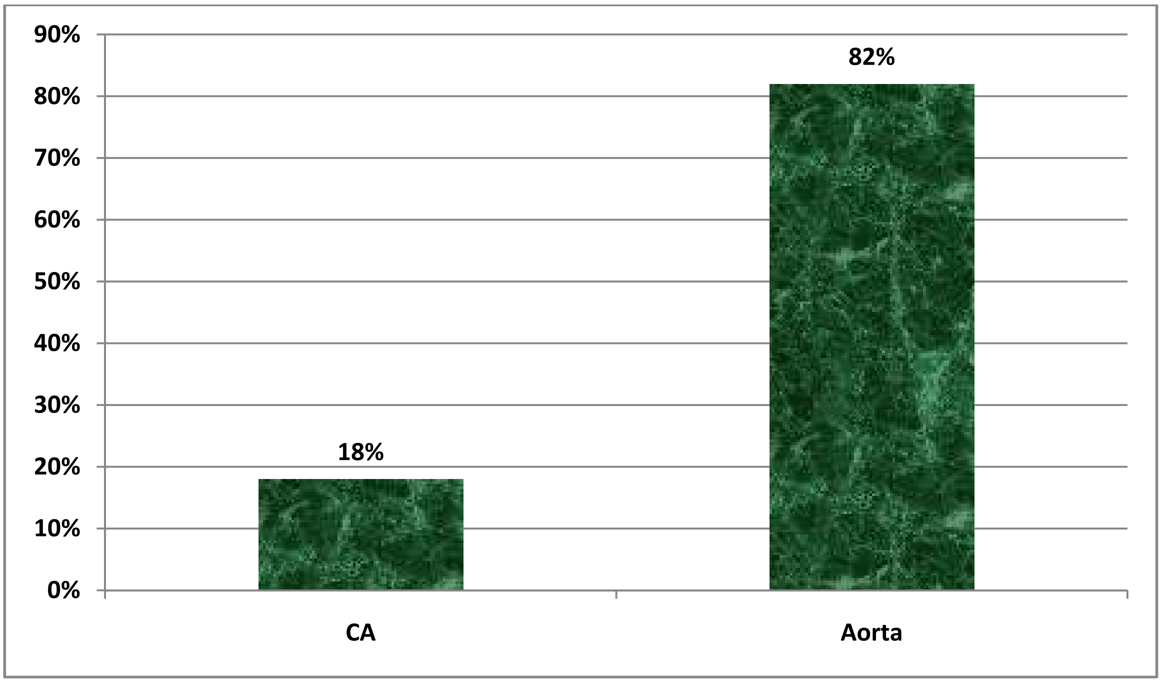
RIPA

Among 50 specimens the RIPA arose from CA in 9 specimens (Fig20). It arose from AA in 41 specimens.

TABLE 10 : SOURCE OF RIPA

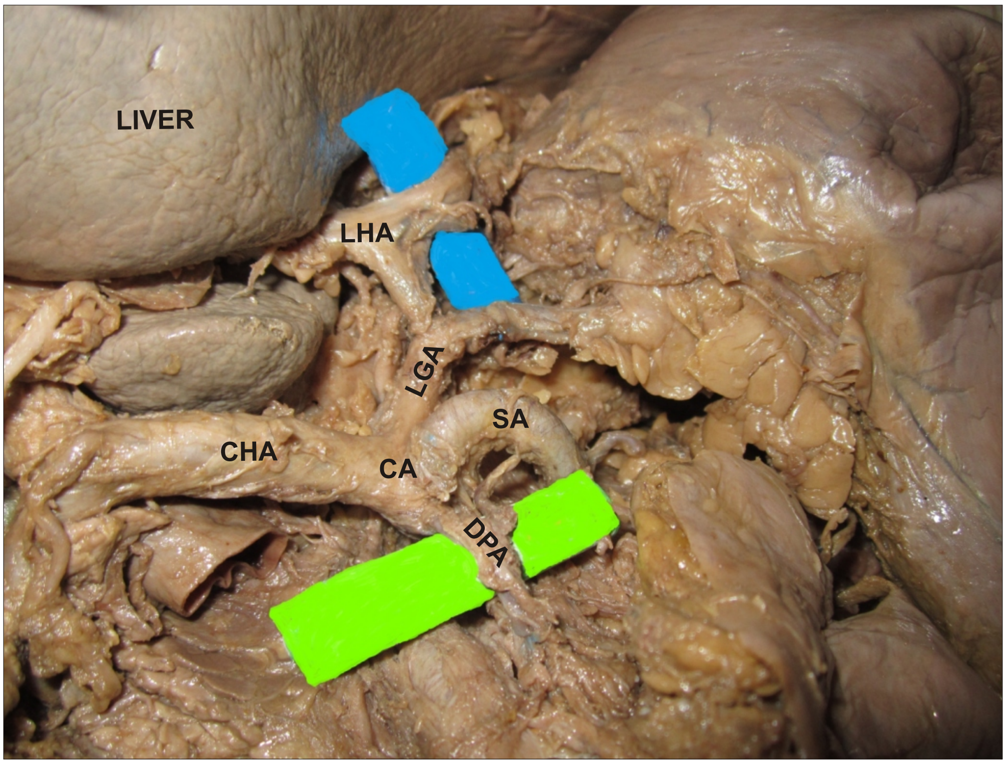
Source of RIPA	Frequency	Percentage
CA	9	18%
Aorta	41	82%

CHART 9 : SOURCE OF RIPA



Of the 50 specimens in 3 specimens both the RIPA and LIPA arose from CA (Fig19), in 6 specimens the RIPA arose from the CA and the LIPA from the AA (Fig20).

Fig. 21B. Dorsal pancreatic artery arising from coeliac artery



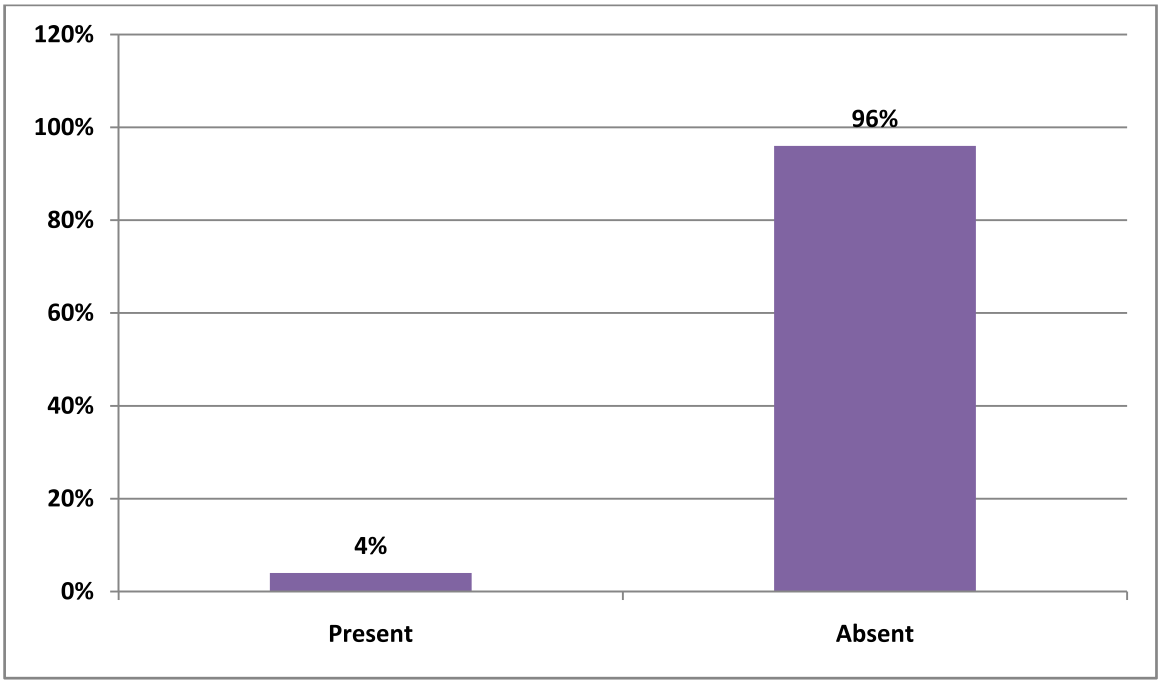
DPA

In 2 specimens the DPA arose from the CA(Fig21 A&B).

TABLE 11 : DPA

DPA	Frequency	Percentage
Present	2	4%
Absent	48	96%

CHART 10 : DPA



ABERRANT BRANCHES

Among the 11 specimens in which aberrant branches were present, in 9 specimens inferior phrenic arteries were the aberrant branches and in 2 specimens DPA was the aberrant branch.

TABLE 12 : ABERRANT BRANCHES FROM CA

Aberrant branch	Frequency	Percentage
IPA	9	18%
DPA	2	4%

CHART 11 : ABERRANT BRANCHES FROM CA

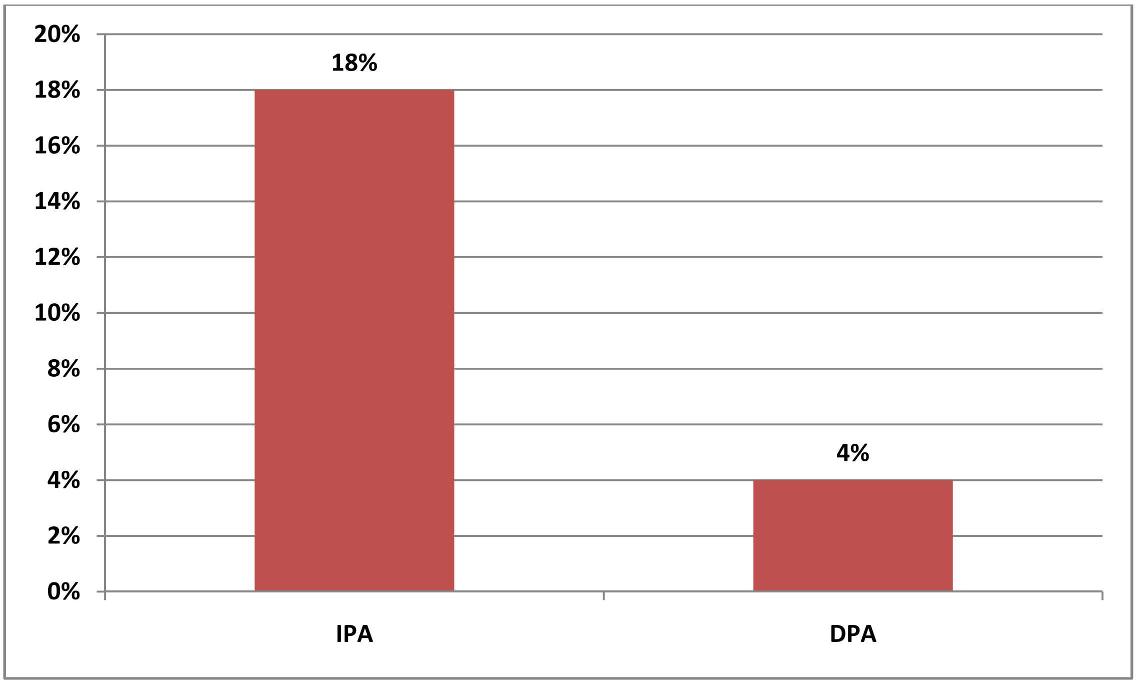


Fig. 22.Normal adult CT coeliac angiogram

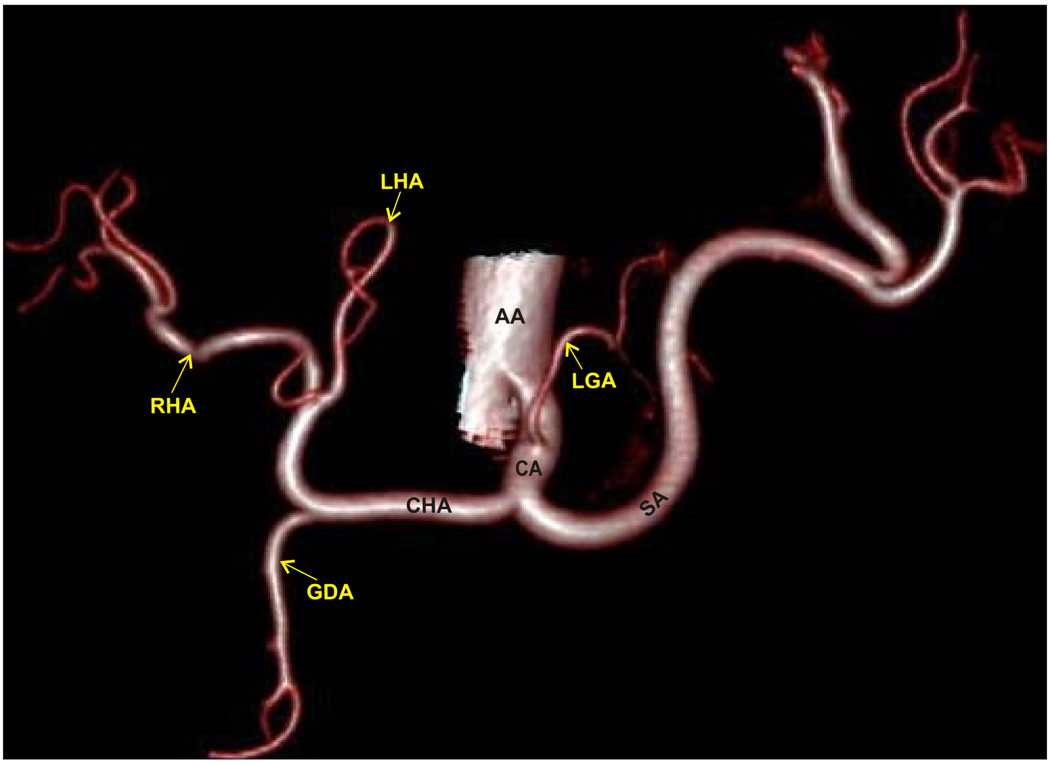


Fig.23.CT angiogram showing classical trifurcation of coeliac artery

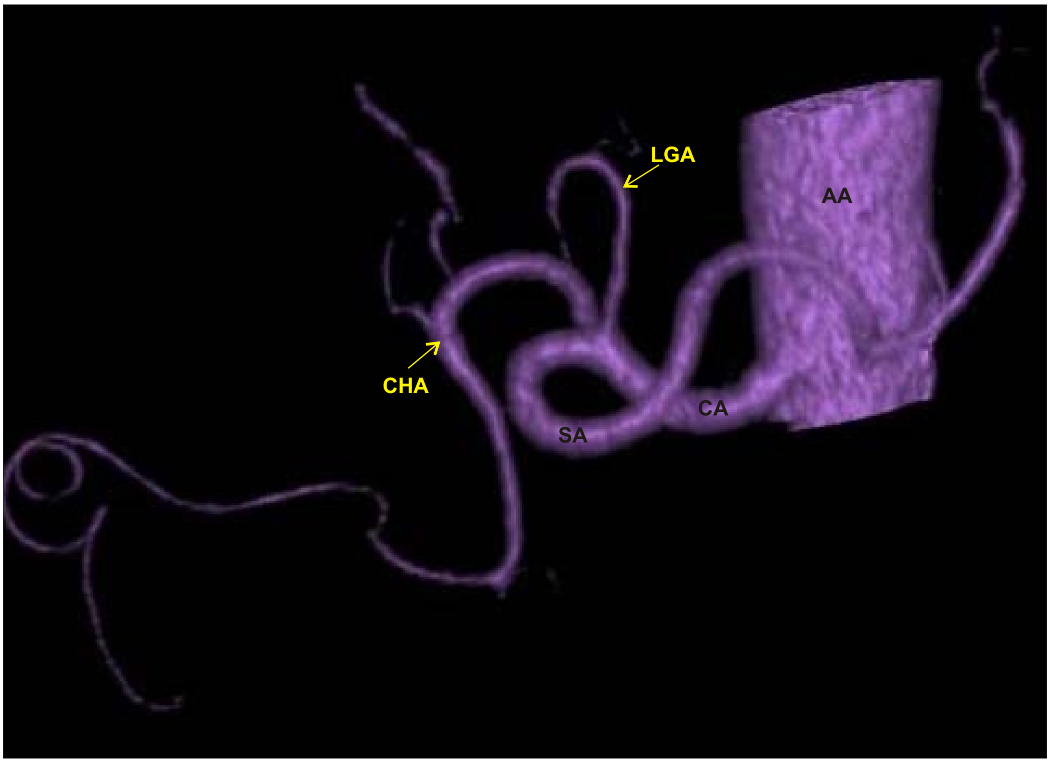


Fig. 24.Coeliac artery is absent with all its branches arising directly from aorta

Fig. 25.Coeliac artery with aberrant branches - LIPA and RIPA

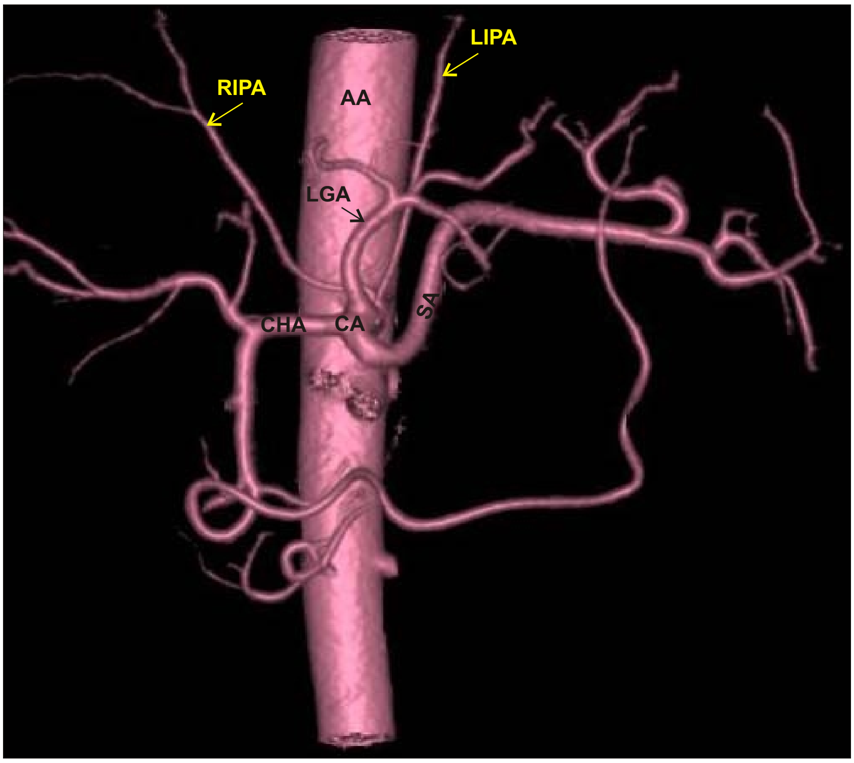


Fig. 26.Coeliac artery with aberrant branch - LIPA

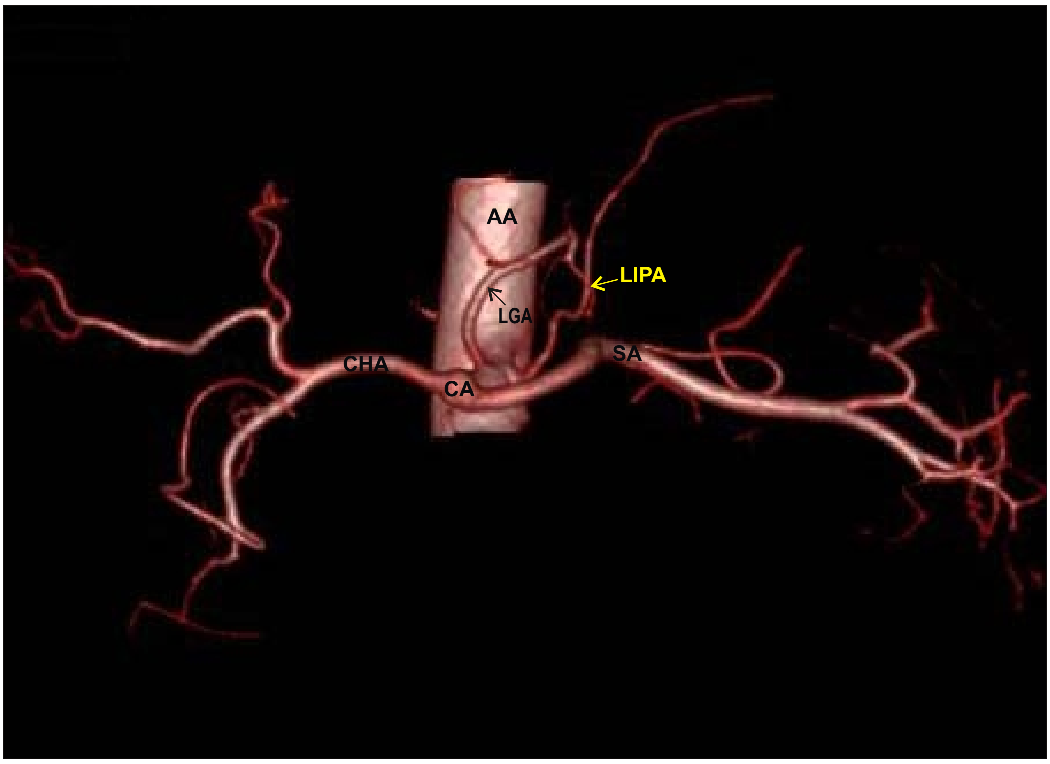


Fig. 27.Coeliac artery with aberrant branch - DPA

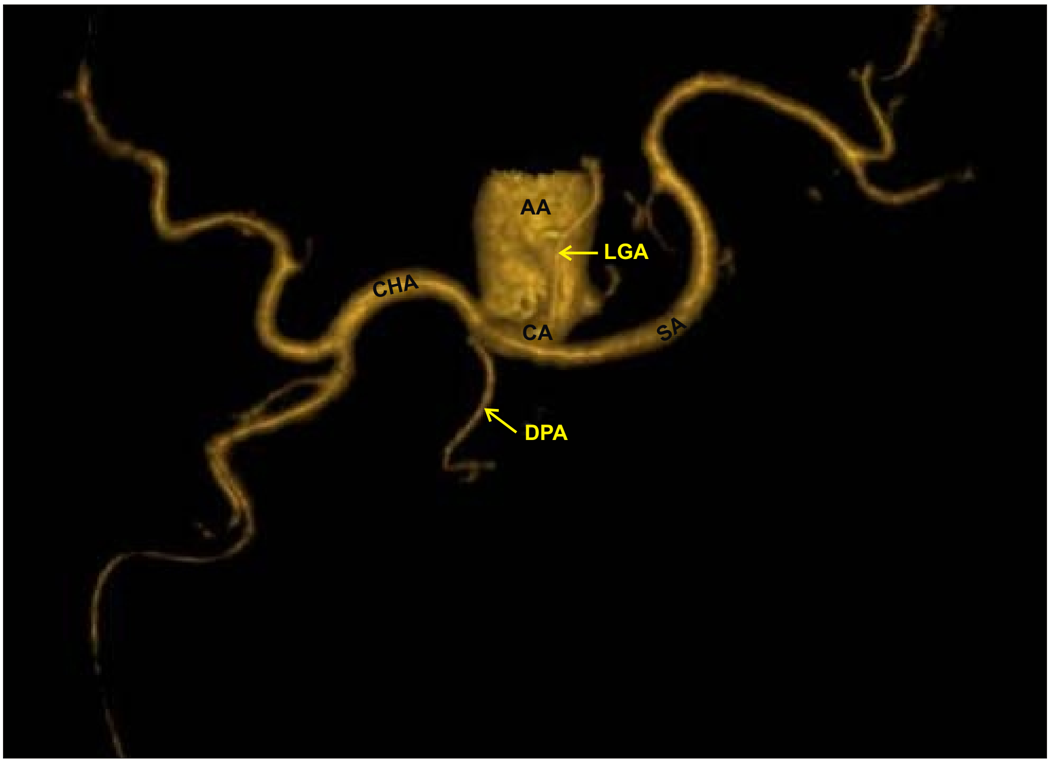


Fig. 28.LHA arising from LGA and RHA arising from SMA with absent CHA

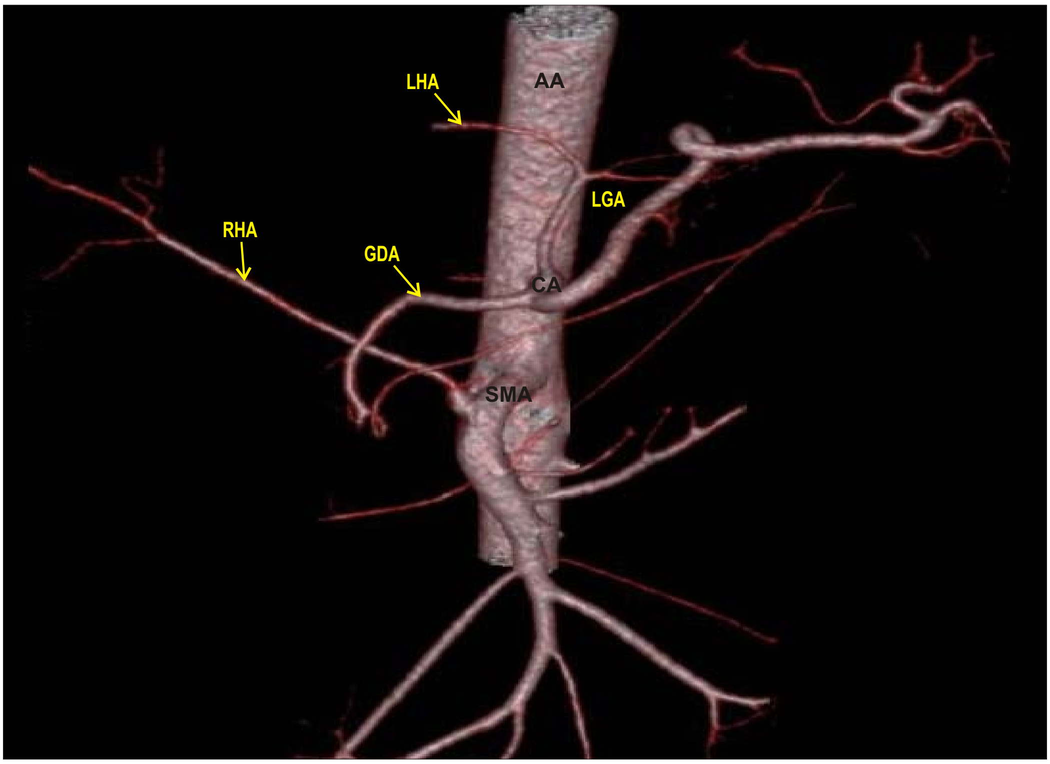


Fig. 29.Left hepatic artery arising from common hepatic artery.

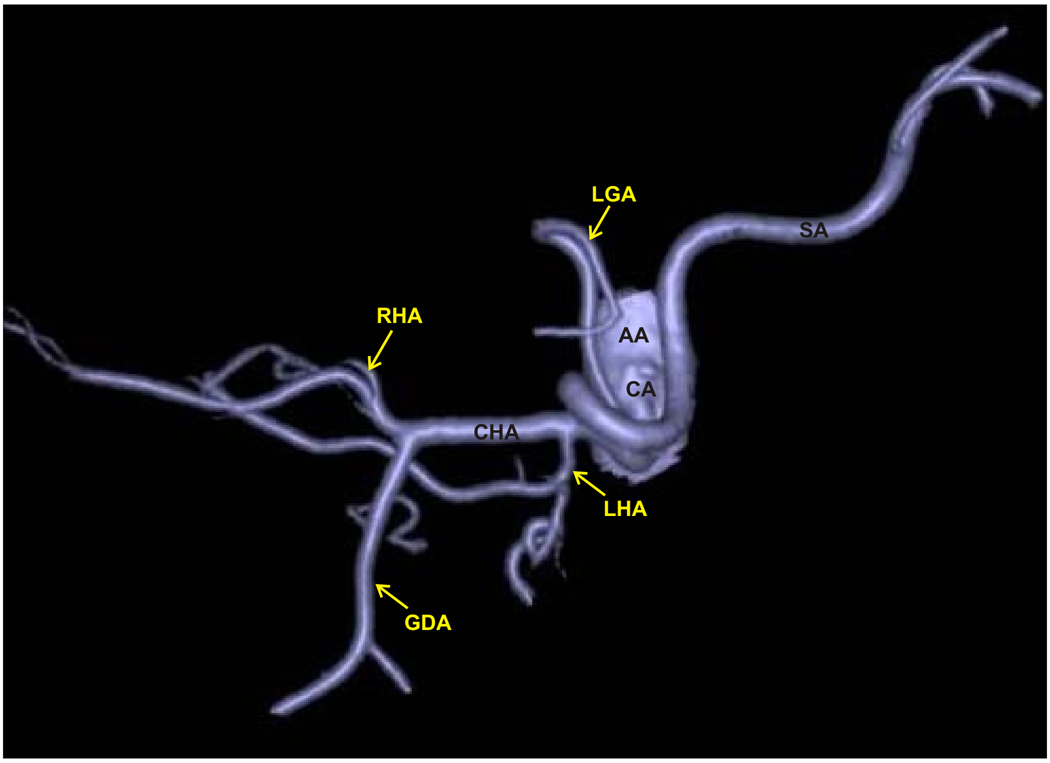
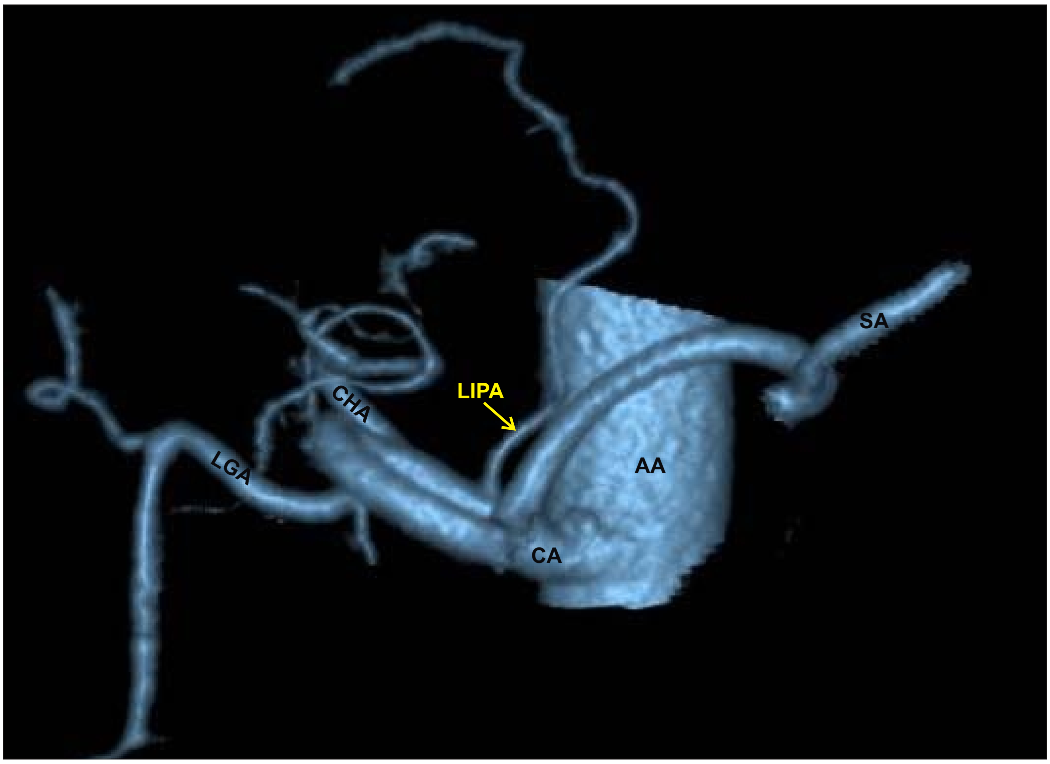


Fig. 30. LIPA arising from coeliac artery



RADIOLOGICAL STUDY

- Among the 25 adult CT coeliac angiograms CA was complete in 19 cases (76%) (Fig22) with classical trifurcation in 1 case (4%) (Fig23).
- It was absent in 1 case (4%) (Fig24).
- It had aberrant branches in 5 cases (20%) (Fig25,26& 27).
- LGA originated from AA in 1 case (4%) (Fig24).
- SA originated from AA in 1 case (4%) (Fig24).
- CHA originated from AA in 1 case (4%) (Fig24).
- LHA arising from LGA and RHA arising from SMA with absent CHA was found in 2 cases (8%) (Fig28).
- LHA arising from CHA was found in 1 case (4%) (Fig29).
- RIPA and LIPA from CA were noticed in 1 case (4%) (Fig25).
- LIPA alone from CA was noticed in 3 cases (12%) (Fig26&30).
- DPA from CA was noticed in 1 case (4%) (Fig27).

Discussion

DISCUSSION

LEVEL OF ORIGIN OF COELIAC ARTERY

J.C. Boileau Grant[5] [1958] stated that the AA gives off CA at the level of T_{12} vertebra.

Pushpalatha[25] [2006] reported that in 6% of the specimens the CA originated at the level of upper border of $T_{12;}$ in 66% it originated at the level of lower border of T_{12} ; in 4% CA originated between T_{12} and L_1; in 24% CA originated at the level of upper border of $L_{1.}$

Ambica Wadhwa et al[2] [2011] reported that the CA originated from AA at the level of inter vertebral disc between T_{12} and L_1 in 73.3% and upper one third of L_1 vertebra in 26.6%.

Chummy S. Sinnatamby[7] [2011] stated that the CA arises from AA at the level of the body of the twelfth thoracic vertebra.

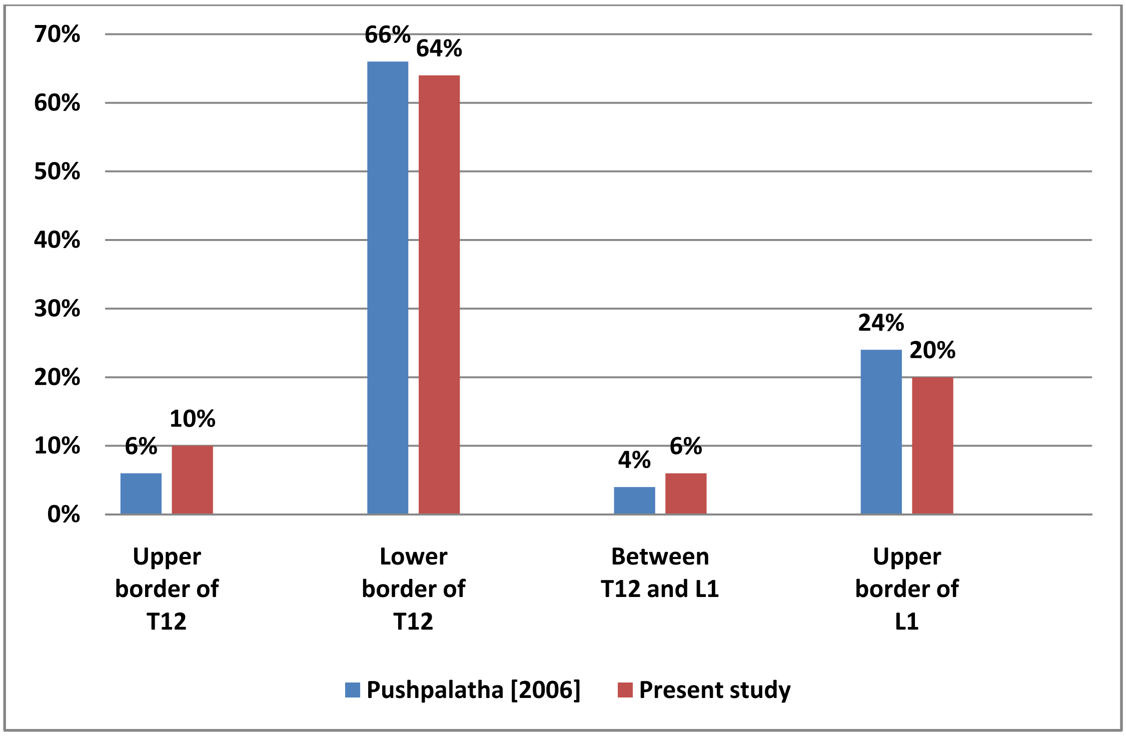
In the present study in 10% the CA originated at the level of upper border of T_{12} . In 64% it originated at the level of lower border of T_{12}; in 6% CA originated between T_{12} and L_1; and in 20% CA originated at the level of upper border of $L_{1.}$ The observations of the present study were similar to the findings of Pushpalatha [2006].

Variation in the level of origin of CA implies that the planning of surgery must be individualized for carcinoma pancreas, stomach, liver and extrahepatic biliary tree as nodes at risk lie near the artery.

TABLE 13 : LEVEL OF ORIGIN OF COELIAC ARTERY

Level of origin of CA	Pushpalatha [2006]	Present study
Upper border of T_{12}	6%	10%
Lower border of T_{12}	66%	64%
Between T_{12} and L_1	4%	6%
Upper border of L_1	24%	20%

CHART 12 : LEVEL OF ORIGIN OF COELIAC ARTERY



ORIGIN OF COELIAC ARTERY IN RELATION TO MEDIAN ARCUATE LIGAMENT OF THE DIAPHRAGM

Harold H. Lindner et al[10] [1971] reported that in 33% the origin of coeliac artery was at or above the level of MAL.

Selma Petrella et al[34] [2006] reported that in 14.46% the MAL was distant from the origin of coeliac artery; in 42.17% , the MAL was touching the origin of CA; and in 43.37% MAL was overlapping the origin of CA.

Susan Standring[39][2008] stated that the origin of CA may be compressed by the right crux of the diaphragm giving the appearance of a stricture.

Chummy S. Sinnatamby[7] [2011] stated that the CA takes origin from AA a little below the MAL.

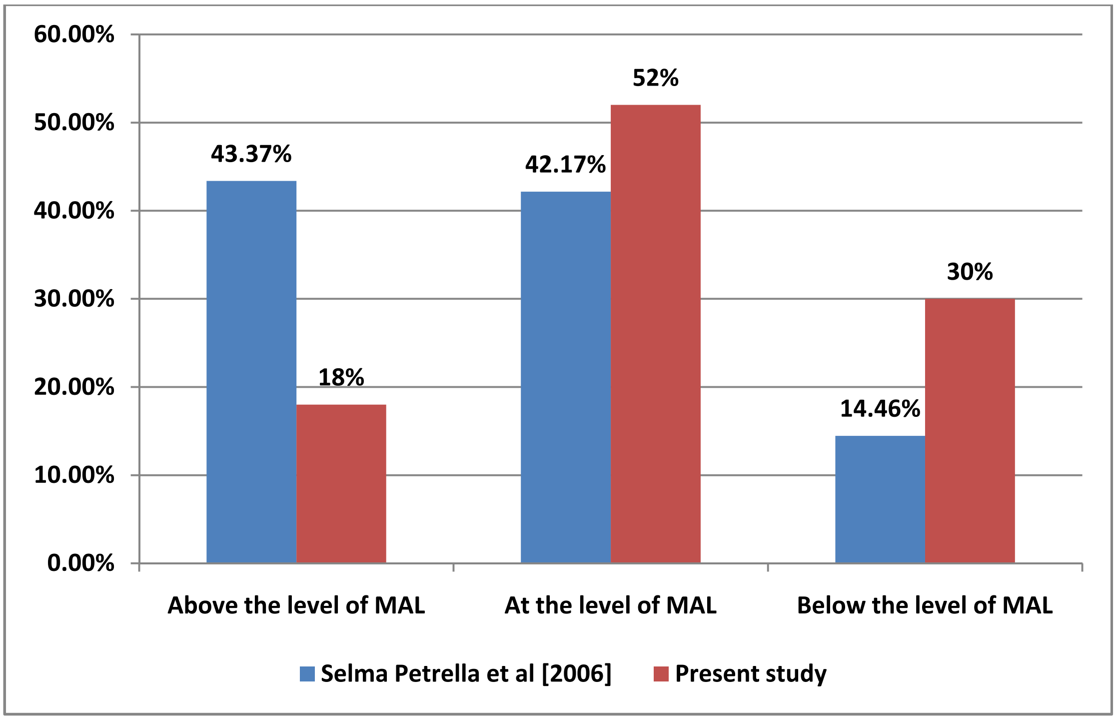
In the present study in 18% the origin of coeliac artery was above the level of MAL; and in 52% the origin of coeliac artery was at the level of MAL and in 30% the origin of coeliac artery was below the level of MAL.

In cases where the CA takes origin above the level of MAL it gets compressed by the MAL causing abdominal pain, loss of appetite and loss of weight, the symptoms of MAL syndrome. These patients are relieved of the symptoms by the surgical division of the MAL.

TABLE 14 ORIGIN OF COELIAC ARTERY IN RELATION TO MEDIAN ARCUATE LIGAMENT OF THE DIAPHRAGM

Origin of CA in relation to MAL	Selma Petrella et al [2006]	Present study
Above the level of MAL	43.37%	18%
At the level of MAL	42.17%	52%
Below the level of MAL	14.46%	30%

CHART 13 : ORIGIN OF COELIAC ARTERY IN RELATION TO MEDIAN ARCUATE LIGAMENT OF THE DIAPHRAGM



LENGTH OF COELIAC ARTERY FROM ITS ORIGIN TO EMERGENCE OF FIRST BRANCH

Benjamin Lipshutz[3] [1917] reported that the length of CA was between 1and 3cm .

Pushpalatha[25] [2006] reported that the length of coeliac artery was between 0.4 and 2.9cm.

Selma Petrella et al[32] [2007] found 1.23cm in male and 1.11cm in female as the mean length of coeliac artery.

Ambica Wadhwa et al[2] [2011] reported the following regarding the length of CA. The range was between 0.8–2.1 cm and most of the cases were between 1-1.3cm.

Prakash et al[24] [2012] stated 1.2-1.4cm as the range of length of coeliac artery.

In the present study the length of CA was between 0.4-2.4cm and mean length was 1.37cm. It was in accordance with the observations made by Pushpalatha and Ambica Wadhwa et al studies.

TABLE 15 : LENGTH OF CA FROM ITS ORIGIN TO EMERGENCE OF FIRST BRANCH

Study	Length of CA from its origin to emergence of first branch
Benjamin Lipshutz [1917]	1 - 3 cm
Pushpalatha [2006]	0.4 – 2.9 cm
Ambica Wadhwa et al [2011]	0.8 – 2.1 cm
Prakash et al [2012]	1.2 – 1.4cm
Present study	0.4 – 2.4 cm

TYPE OF COELIAC ARTERY

Benjamin Lipshutz[3] [1917] stated that in 72.2% of the specimens the CA was complete with all the three classic branches, the LGA, SA and CHA arising from it. In 25% of the specimens it was incomplete with any one of the three branches arising directly from AA. He reported that the incidence of coeliaco mesenteric trunk was 2.4%.

J.C. Boileau Grant[5] [1958] stated that the CA divides into three branches, the LGA, SA and CHA.

G.J. Romanes[29] [1972] stated that the coeliac artery divides into three branches the LGA, SA and CHA. He also stated that the CA may be absent with its branches arising independently from AA.

W.HenryHollinshead[11] [1975] stated that the CA gives rise to three branches of which the LGA originates first followed by bifurcation into SA and CHA.

R. M. Jones et al[14] [2001] reported that in 92% of the specimens the coeliac artery was complete; in 1.7% it was incomplete with LGA taking origin from a different source; in 1.6% it took origin along with SMA from AA as the coeliaco mesenteric trunk. In 1.1% the CA was absent. They stated that in 0.6% the aberrant branches arose from CA.

Muhammad Saeed et al[19] [2003] stated that in 88.3% of the specimens the CA was complete and in 1.9% it was incomplete with the CHA arising from the SMA. In 9.6% of the specimens there were aberrant branches (IPA) arising from the CA.

Pushpalatha[25] [2006] stated that in 72% of specimens the CA was complete, in 4% it was incomplete with CHA arising directly from AA. She also reported that in 4% CA was absent with all the three branches taking origin from AA. The incidence of aberrant branches was 20% among which 18% was IPA and 2% was DPA.

Selma Petrella et al[32] [2007] reported that in 82.02% of the specimens the CA was complete, in 6.6% it was incomplete and in 1.12% it was absent. In 7.86% of specimens there were other branches arising from the CA namely the GDA and middle colic artery. In 2.25% Acc. HA arose from CA.

M S Ugurel et al[40] [2010] reported that in 89% of the specimens the CA was complete, in 8% it was incomplete and in 1% it was absent. In 1%

hepatosplenomesenteric trunk and in 1% splenomesenteric trunk were present.

Mburu K S et al[18] [2010] reported that in 61.7% of the specimens the CA was complete, in 17.9% it was incomplete and in 20.3% aberrant branches were present.

Ambica Wadhwa et al[2] [2011] reported that in 93.3% of the specimens the CA was complete, in 6.6% it was incomplete.

Prakash et al[24] [2012] reported that in 86% of the specimens the CA was complete, in 10% it was incomplete and in 4% it was absent.

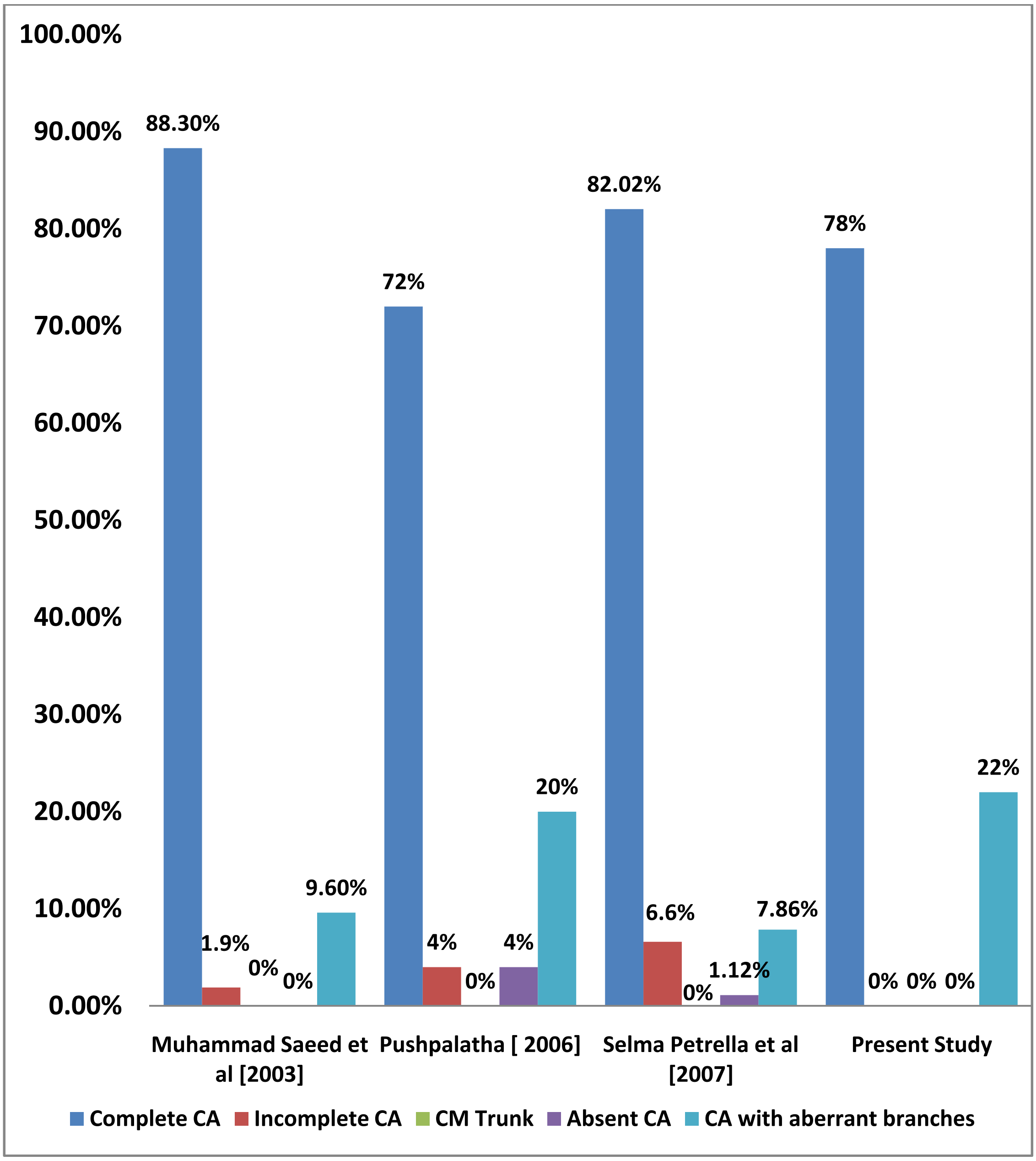
In the present study it was observed that in 78% of the specimens the CA was complete and in 22% there were aberrant branches (in 18% IPA were present and in 4%, DPA were present) arising from the CA in addition to the 3 classic branches which was similar to observations made by Pushapalatha, Selma Petrella et al and Muhammad Saeed et al studies. The previous studies reported incomplete CA and absent CA which was not observed in this study.

Knowledge of the type of CA is necessary to avoid inadvertent ligation of other vessels. The variant anatomy must be recognized by diagnostic angiography before doing any interventional or invasive procedure of the abdomen.

TABLE 16 : TYPE OF COELIAC ARTERY

Study	Complete	Incomplete	CM Trunk	Absent	Aberrant
Muhammad Saeed et al [2003]	88.3%	1.9%	-	-	9.6%
Pushpalatha [2006]	72%	4%	-	4%	20%
Selma Petrella et al [2007]	82.02%	6.6%	-	1.12%	7.86%
Present Study	78%	-	-	-	22%

CHART 14 : TYPE OF COELIAC ARTERY



BRANCHES OF COELIAC ARTERY

LEFT GASTRIC ARTERY

J.C. Boileau Grant[5] [1958] stated that LGA takes origin from CA.

G.J Romanes[29] [1972] stated that CA gives rise to LGA.

R. M. Jones et al[14] [2001] stated that in 96.7% of the cases LGA arose from CA ;in 2.2% LGA arose from AA; and in 1.1% from SA.

Pushpalatha[25] [2006] reported that in 96% of the cases LGA arose from CA and in 4% LGA arose from AA.

Selma Petrella et al[32] [2007] stated that in 95.52% of the cases LGA arose from CA and in 4.48% LGA arose from AA.

Randjelovic D T et al[27] [2007] stated that in 98.2% of the cases LGA arose from CA and in 1.8% LGA arose from AA.

Ambica Wadhwa et al[2] [2011] stated that in 93.3% of the cases LGA arose from CA and in 6.6% LGA arose from AA.

Chummy S. Sinnatamby[7] [2011] stated that LGA arises from CA.

Sunita U. Sawant et al[38] [2013] stated that in 98% of the cases LGA arose from CA and in 2% LGA arose from AA.

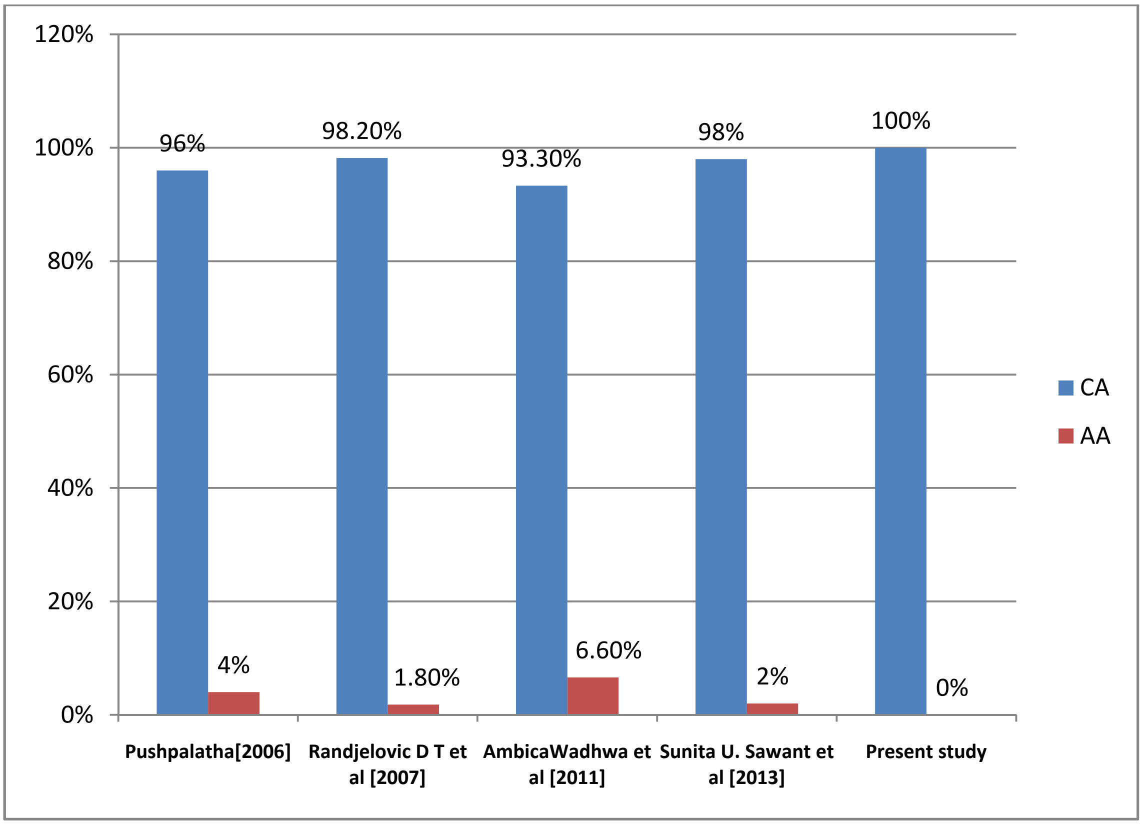
In the present study in all 50 specimens LGA arose from CA as stated by J.C. Boileau Grant, G.J Romanes and Chummy S. Sinnatamby. In none of the cases LGA arose from AA as observed in the previous studies.

Knowledge regarding the source of LGA is essential when treating patients with gastrointestinal bleeding caused by gastric and duodenal ulcers as ligation of the vessel is required. Recognizing the variant anatomy is required before doing gastrectomy and other radical procedures to treat malignancies of the oesophagus and stomach. Ligation of LGA must be done carefully keeping in mind the aberrant branches namely the replaced and accessory LHA, as inadvertent ligation in this case causes ischemia and necrosis of the left lobe of the liver.

TABLE 17 : SOURCE OF LGA

Source of LGA	CA	AA
Pushpalatha [2006]	96%	4%
Randjelovic D T et al [2007]	98.2%	1.8%
AmbicaWadhwa et al [2011]	93.3%	6.6%
Sunita U. Sawant et al [2013]	98%	2%
Present study	100%	-

CHART 15 : SOURCE OF LGA



SPLENIC ARTERY

Benjamin Lipshutz[3] [1917] stated that in 94% SA originated from CA and in 6% SA originated from AA.

J.C. Boileau Grant[5] [1958] stated that SA takes origin from CA.

G.J Romanes[29] [1972] stated that CA gives rise to SA.

Vandamme J.P. et al[41] [1986] stated that variations in the origin of SA are very rare.

R. M. Jones et al[14] [2001] reported that in 98.4% SA originated from CA and in 1.6% SA originated from AA.

Selma Petrella et al[32] [2007] reported that in 97.76% SA originated from CA and in 2.24% SA originated from AA.

M S Ugurel et al[40] [2010] reported that in 97% SA originated from CA and in 2% SA originated from AA. In 1% it originated along with SMA as splenomesenteric trunk.

Soon-Young Song et al[37] [2010] reported that in 98.4% SA originated from CA and in 0.36% SA originated from AA. In 1.26% ambiguous anatomy was present.

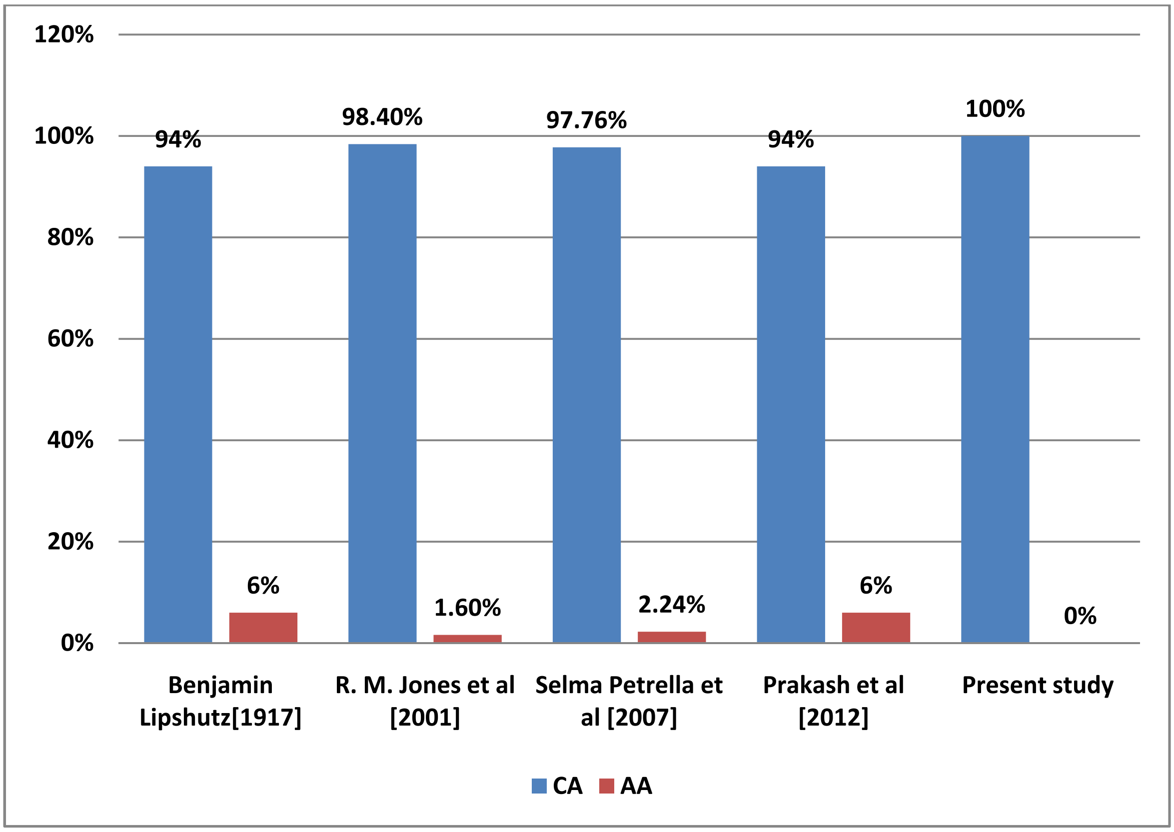
Prakash et al[24] [2012] reported that in 94% SA originated from CA and in 6% from AA.

In the present study in all the 50 specimens the SA arose from CA.

TABLE 18 SOURCE OF SA

Source of SA	CA	AA
Benjamin Lipshutz [1917]	94%	6%
R. M. Jones et al [2001]	98.4%	1.6%
Selma Petrella et al [2007]	97.76%	2.24%
Prakash et al [2012]	94%	6%
Present study	100%	-

CHART 16 : SOURCE OF SA



Knowledge regarding the source of splenic artery is essential while doing splenectomy for treating haematological diseases and haemoperitoneum due to splenic rupture.

COMMON HEPATIC ARTERY

J.C. Boileau Grant[5] [1958] stated that CHA takes origin from CA.

G.J Romanes[29] [1972] stated that CA gives rise to CHA. He also stated that CHA or accessory HA may arise from SMA.

W. Henry Hollinshead[11] [1975] stated that in 4% CHA/PHA arises from SMA/AA/LGA and in 96% it arises from CA.

Jonathan R. Hiatt et al[13] [1994] reported that in 96% the CHA arose from CA ; in 1.5% it arose from SMA; and in 0.2% it arose from AA. In 2.3% of the cases there was a combination of replaced or accessory LHA and replaced or accessory RHA.

R. M. Jones et al[14] [2001] reported that in 98.3% the CHA arose from CA;in 0.6% it arose from SMA and in 1.1% it originated from AA.

Koops et al[17] [2004] reported that in 94% the CHA arose from CA; in 2.8% it arose from SMA and in 0.2% it arose from AA. In 3% combined anomalous origin of LHA and RHA were present.

S S Abdullah et al[36] [2006] reported that in 89.6% the CHA arose from CA ; in 1.6% it arose from SMA and in 0.3% it arose from AA. In 8.5% combined anomalous origin of LHA and RHA were present.

Yang S H et al[43] [2007] reported that in 97.7% the CHA arose from CA and in 2.34% it arose from SMA.

M S Ugurel et al[40] [2010] reported that in 96% the CHA arose from CA ; in 2% it arose from SMA and in 1% it arose from AA. In 1% combined anomalous origin of LHA and RHA were present.

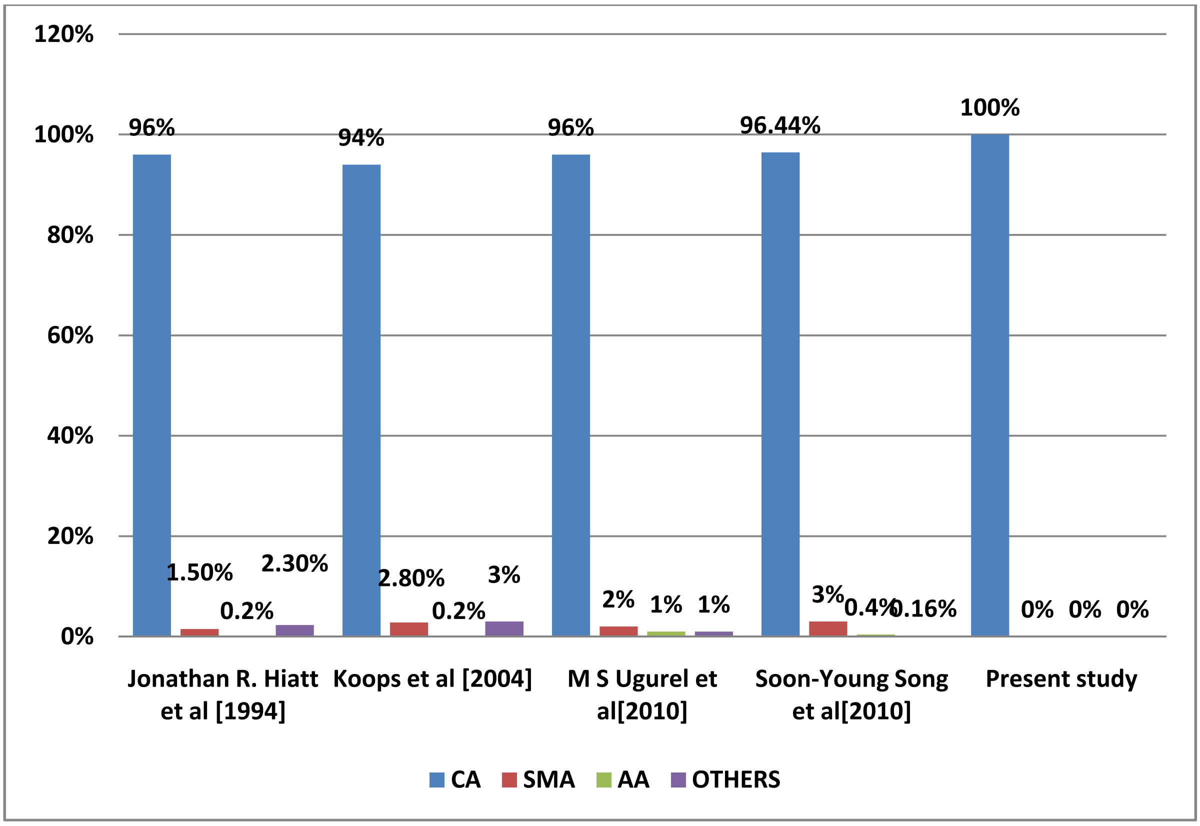
Soon-Young Song et al[37] [2010] reported that in 96.44% the CHA arose from CA ; in 3% it arose from SMA ; in 0.4% it arose from AA and in 0.16 from LGA.

In the present study in all the specimens the CHA arose from CA as quoted by J.C. Boileau Grant

TABLE 19 : SOURCE OF CHA

Source of CHA	CA	SMA	AA	others
Jonathan R. Hiatt et al [1994]	96%	1.5%	0.2%	2.3%
Koops et al [2004]	94%	2.8%	0.2%	3%
M S Ugurel et al[2010]	96%	2%	1%	1%
Soon-Young Song et al[2010]	96.44%	3%	0.4%	0.16%
Present study	100%	-	-	-

CHART 17 : SOURCE OF CHA



Knowledge of the variations in hepatic arterial anatomy is very essential while performing liver transplantation surgeries, laparoscopic procedures. During transplantation procedures clamping or ligation of CHA without knowing that it trifurcates into LHA,RHA and GDA causes gastric or duodenal hypoperfusion in the donor.A replaced CHA from SMA increases the complexity of the surgery. It is also essential to determine the source of the artery which feeds the tumour for correct placement of chemo pumps and for doing embolisation.

LEFT HEPATIC ARTERY

J.C. Boileau Grant[5] [1958] stated that in 88.5% LHA arises from PHA and in 11.5% replaced LHA arises from LGA.

G.J. Romanes[29][1972] stated that LHA or accessory HA may arise from LGA.

W. Henry Hollishead[11] [1975] stated that accessory or replaced LHA arises from LGA

Muhammad Saeed et al[19] [2003] reported that in 92.4% the LHA arose from PHA and in 7.6% it arose from LGA.

Koops et al[17] [2004] reported that in 94% the LHA arose from PHA and in 4.3% it arose from LGA. In 1.7% it arose from CA.

Pushpalatha[25] [2006] stated that in 76% LHA arose from PHA ; in 12% from CHA; and in 12% from LGA.

S S Abdullah et al[36] [2006] reported that in 81.1% the LHA arose from PHA ; in 14.5% it arose from LGA and in 2.3% it arose from CHA. In 2.1% it arose from CA.

Randjelovic D. T. et al[27] [2007] reported that in 98% the LHA arose from PHA and in 1.6% it arose from LGA. In 0.4% it arose from CA. Accessory LHA arose from LGA in 4.4%.

Corinne B. Winston et al[8] [2007] reported that in 87.9% the LHA arose from PHA; in 7.6% it arose from LGA and in 4.3% it arose from CHA. In 0.2% it arose directly from CA. Accessory LHA arose from LGA in 4%

Susan Standring[39][2008] stated that replaced or accessory LHA arises from LGA. She also stated that the CHA may trifurcate into LHA,RHA and GDA.

M S Ugurel et al[40] [2010] reported that in 87% the LHA arose from PHA; in 12% it arose from LGA and in 1% it arose from CHA. Accessory LHA arose from LGA in 12%.

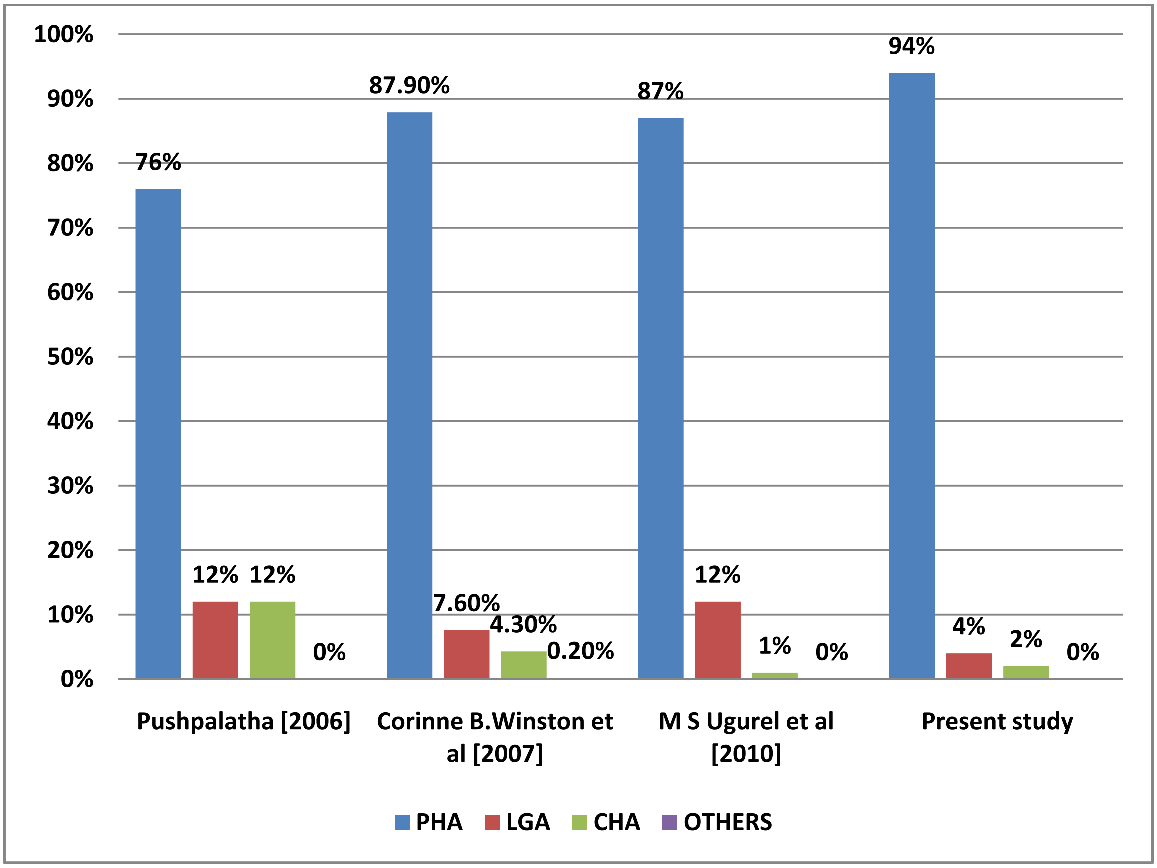
Binit Sureka et al[4] [2013] reported that in 89.1% the LHA arose from PHA ; in 10.5% it arose from LGA and in 0.3% it arose from AA. Accessory LHA arose from LGA in 7.6%.

In the present study the LHA arose from PHA in 94%, from LGA in 4% and directly from CHA in 2%. The findings of the present study were comparable to the findings of Pushpalatha, Corinne B. Winston et al, M S Ugurel et al studies.

TABLE 20 : SOURCE OF LHA

Source of LHA	**PHA**	**LGA**	**CHA**	**OTHERS**
Pushpalatha [2006]	76%	12%	12%	-
Corinne B. Winston et al [2007]	87.9%	7.6%	4.3%	0.2%
M S Ugurel et al [2010]	87%	12%	1%	-
Present study	94%	4%	2%	-

CHART 18 : SOURCE OF LHA



In the present study accessory LHA arose from LGA in 4%. This finding was similar to the findings of Randjelovic D T et al, Corinne B. Winston et al, Binit Sureka et al studies.

TABLE 21 INCIDENCE OF ACCESSORY LHA

Study	Incidence of accessory LHA
Randjelovic D T et al [2007]	4.4%
Corinne B. Winston et al [2007]	4%
M S Ugurel et al [2010]	12%
Binit Sureka et al [2013]	7.6%
Present study	4%

Recognition of hepatic arterial variants is indispensible before performing liver transplantation surgeries. Ligation of CHA when the LHA emerges from it before GDA, causes gastric or duodenal hypoperfusion in the donor. Replaced or Acc. LHA increases the complexity of the surgery.

RIGHT HEPATIC ARTERY

Jonathan R. Hiatt et al[13] [1994] reported that in 87.1% the RHA arose from PHA and in 12.9% it arose from SMA.

Muhammad Saeed et al[19] [2003] reported that in 96.2% the RHA arose from PHA and in 3.8% it arose from SMA.

Koops et al[17] [2004] reported that in 85.1% the RHA arose from PHA and in 13.2% it arose from SMA. In 1.7% RHA arose from CA.

Pushplalatha[25] [2006] stated that in 76% RHA arose from PHA ; in 20% from CHA and in 4% from GDA.

S S Abdullah et al[36] [2006] reported that in 79% the RHA arose from PHA ; in 16.6% it arose from SMA and in 2.3% it arose from CHA. In 2.1% arose from CA.

Randjelovic D T et al[27] [2007] reported that in 98.5% the RHA arose from PHA and in 1.1% it arose from SMA. In 0.4% LHA arose from CA.

Corinne B. Winston et al[8] [2007] reported that in 77.7% the RHA arose from PHA; in 13.7% it arose from SMA and in 3.8% it arose from CHA. In 4.8% RHA arose from GDA and CA.

Susan Standring[39] [2008] stated that replace or accessory RHA arises from SMA. She also stated that the CHA may trifurcate into LHA,RHA and GDA.

M S Ugurel et al[40] [2010] stated that RHA originated from PHA in 79%; from SMA in 19%; from middle colic artery in 1% and from AA in 1%. Accessory RHA was present in 2%.

Chummy S. Sinnatamby[7] [2011] stated that RHA may take origin from SMA in 15% and from PHA in 85%.

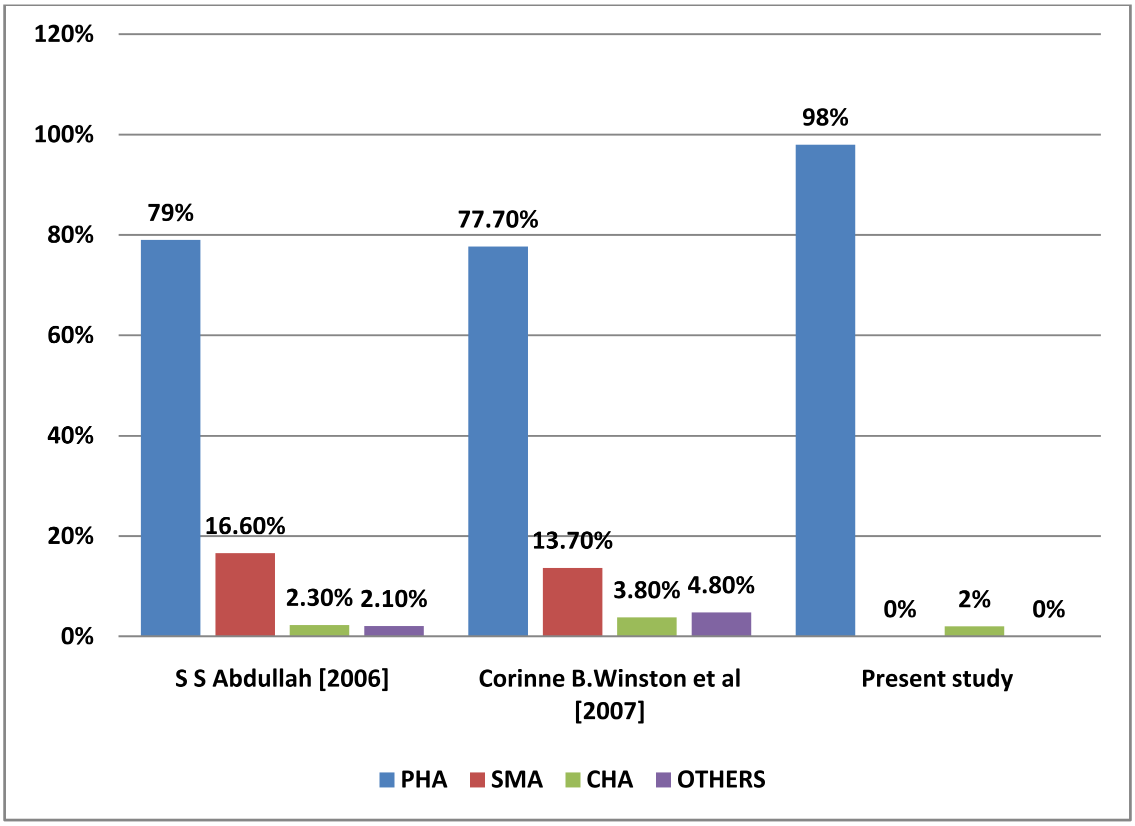
Binit Surekha et al[4] [2013] reported that in 84.9% the RHA arose from PHA; in 13.5% it arose from SMA; in 1.3% from CA and in 0.3% from aorta.

In the present study the RHA arose from PHA in 98% and arose directly from CHA in 2% which was similar to the observations made by S S Abdullah et al and Corinne B. Winston et al studies.

TABLE 22 : SOURCE OF RHA

Source of RHA	PHA	SMA	CHA	OTHERS
S S Abdullah et al [2006]	79%	16.6%	2.3%	2.1%
Corinne B. Winston et al [2007]	77.7%	13.7%	3.8%	4.8%
Present study	98%	-	2%	-

CHART 19 : SOURCE OF RHA



Knowledge regarding the variation in hepatic vasculature is essential in performing invasive procedures of the upper abdomen. During transplantation surgeries a RHA from CHA before the origin of GDA or a short RHA increases surgical complexity. In that case ligation of CHA can cause gastric or duodenal hypoperfusion. The laparoscopic view of the porta hepatis is altered when RHA takes origin from SMA or CHA.

ABERRANT BRANCHES

THE LEFT INFERIOR PHRENIC ARTERY

Benjamin Lipshutz[3] [1917] stated that the LIPA arose from CA in 15.6% of cases.

Nakamura Y et al[21] [2003] reported 3 cases of Gastrosplenic and Hepatomesenteric trunks. LIPA originated from the Gastrosplenic trunk.

Bulent Yalcin et al[6] [2004] reported a case of 25 year old in which the common stem of LIPA and LGA originated from CA.

Pushpalatha[25] [2006] stated that LIPA arose from CA in 18% of cases.

Selma Petrella et al[33] [2006] reported the following findings. IPA arose from CA in 34.83% of cases, among which LIPA arose in 21.35% of cases.

S. R. Nayak et al[22] [2008] reported a case of CA in which it gave origin to LIPA in addition to its classic branches.

Susan Standring[39] [2008] stated that one or both the RIPA and LIPA may orginate from CA either independently or as a common stem.

Salve VM et al[30] [2011] reported a case of CA in which the LIPA took origin as the first branch.

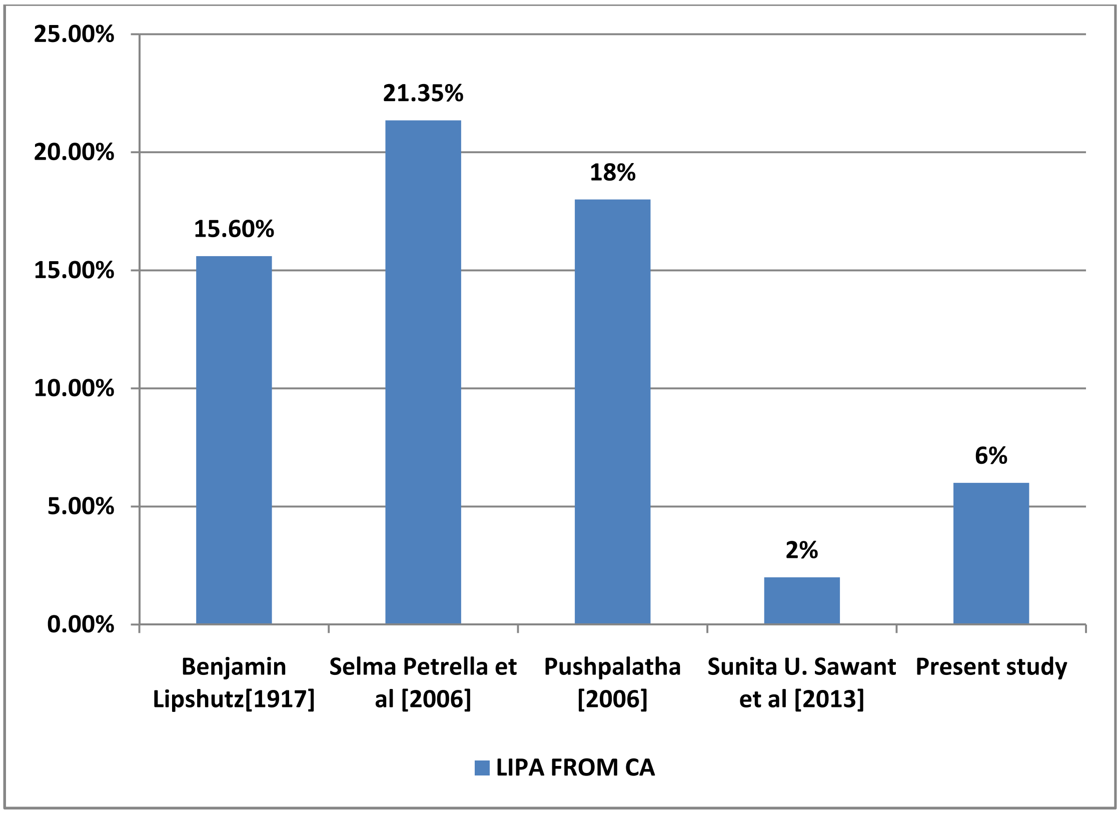
Sunita U. Sawant et al[38] [2013] reported that LIPA took origin from CA in 2% of cases.

In the present study in 6% of the cases LIPA took origin from CA which differed from the findings of the previous studies.

TABLE 23 : INCIDENCE OF LIPA FROM CA

Incidence of LIPA from CA	Percentage
Benjamin Lipshutz[1917]	15.6%
Selma Petrella et al [2006]	21.35%
Pushpalatha [2006]	18%
Sunita U. Sawant et al[2013]	2%
Present	6%

CHART 20 : INCIDENCE OF LIPA FROM CA



THE RIGHT INFERIOR PHRENIC ARTERY

Pushpalatha[25] [2006] stated that RIPA arose from CA in 4% of cases.

Selma Petrella et al[33] [2006] reported the following findings. IPA arose from CA in 34.83% of cases. RIPA alone arose in 5.62% of cases.

Susan Standring[39] [2008] stated that one or both the RIPA and LIPA may orginate from CA either independently or as a common stem.

Mburu K S et al[18] [2010] stated the presence of aberrant branches in 20.3% of the cases studied among which RIPA were present in 4.9% of the cases.

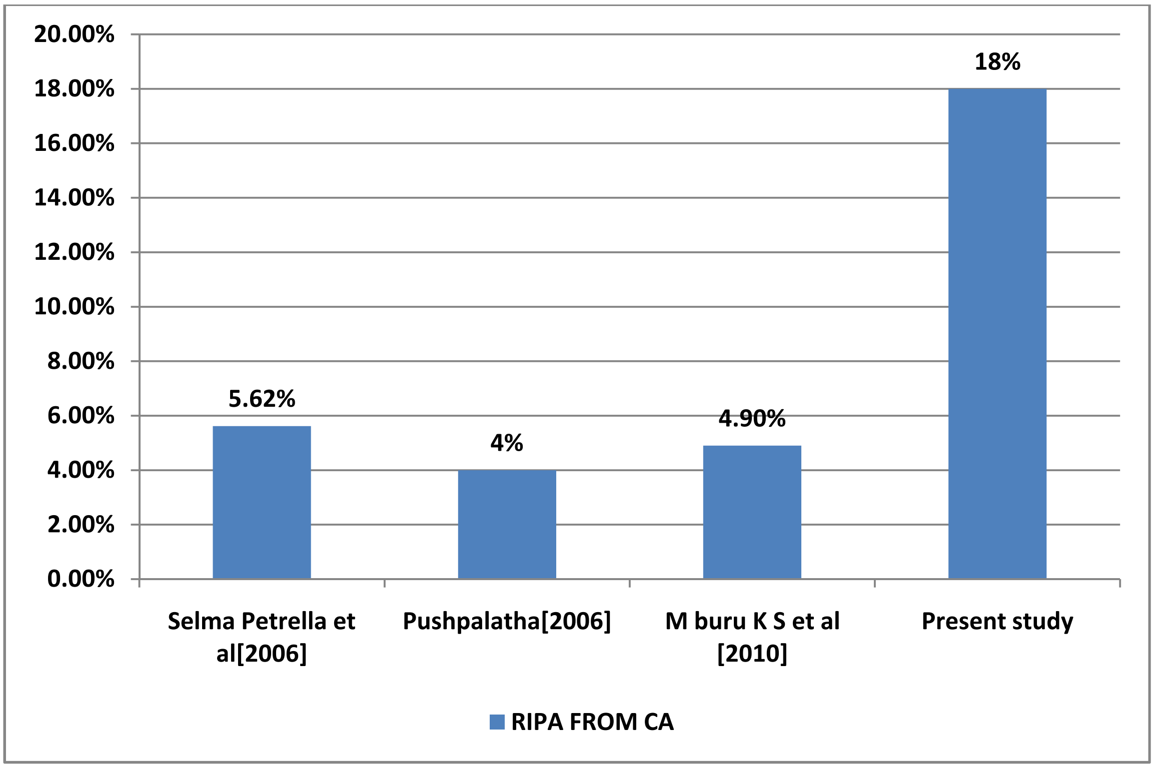
Rajesh B.Astik et al[26] [2011] reported a case where RIPA originated from CA.

In the present study in 18% of the cases the RIPA emerged from CA which differed from the observations of the previous studies.

TABLE 24 : INCIDENCE OF RIPA FROM CA

Incidence of RIPA from CA	Percentage
Selma Petrella et al [2006]	5.62%
Pushpalatha[2006]	4%
Mburu K S et al[2010]	4.9%
Present study	18%

CHART 21 : INCIDENCE OF RIPA FROM CA



THE RIGHT AND THE LEFT INFERIOR PHRENIC ARTERIES

Muhammad Saeed et al[19] [2003] stated that both the IPA arose directly from CA either separately or as a common stem in 9.6% of cases.

Selma Petrella et al[33] [2006] reported the following findings. IPA arose from CA in 34.83% of cases.Both arose from CA in 5.62% of cases. Both arteries arose as a single stem in 2.25% of cases.

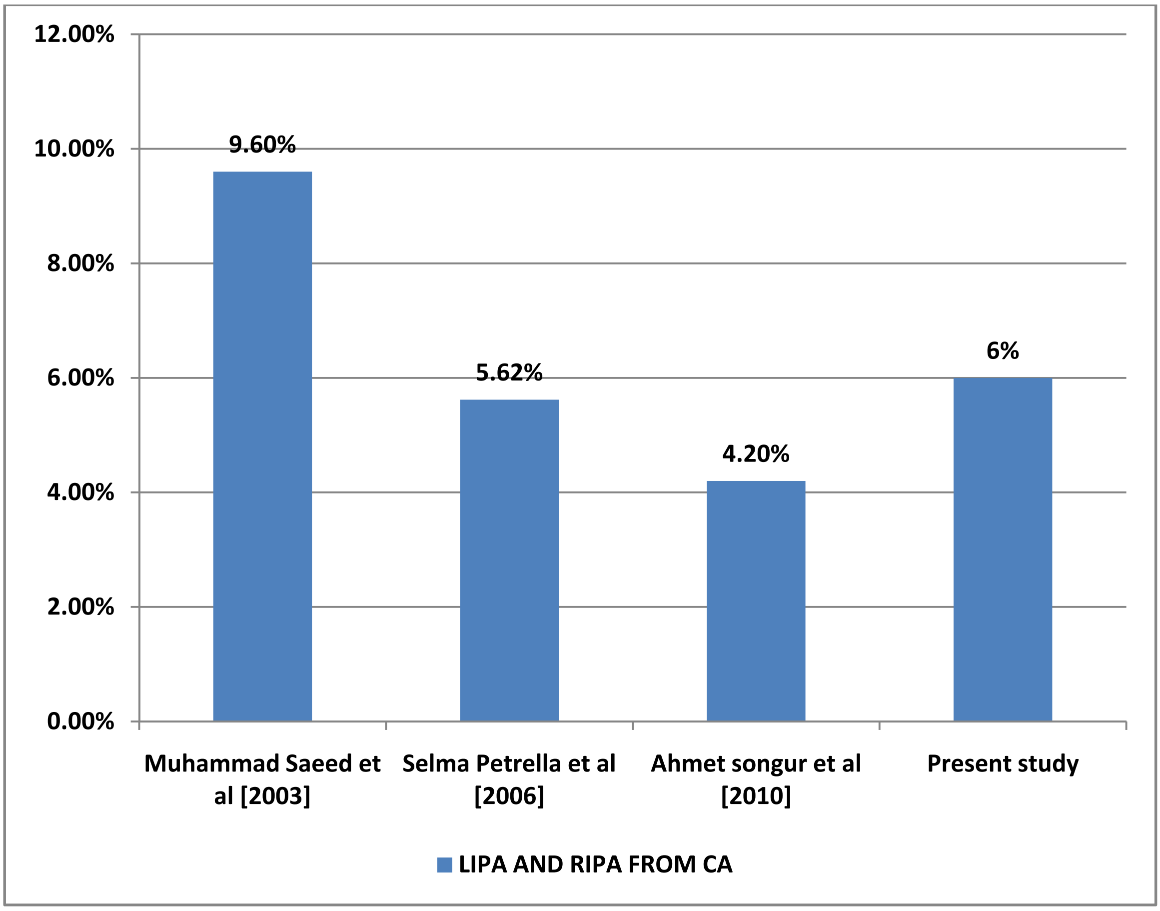
Ahmet Songur et al[1] [2010] stated that the IPA originated from CA as a single stem in 4.2% of cases.

In the present study in 6% of the specimens both the IPAs originated from CA. The findings of present study is similar to those of the previous studies.

TABLE 25 : INCIDENCE OF BOTH THE LIPA AND RIPA FROM CA

Incidence of both the LIPA and RIPA from CA	Percentage
Muhammad Saeed et al [2003]	9.6%
Selma Petrella et al [2006]	5.62%
Ahmet Songur et al [2010]	4.2%
Present study	6%

CHART 22 : INCIDENCE OF BOTH THE LIPA AND RIPA FROM CA



Knowledge about the source of IPAs and its variant anatomy is essential prior to doing transcatheter chemoembolisation in treatment of hepatocellular carcinoma as these arteries are equally important as hepatic arteries in feeding the tumor.

GASTRODUODENAL ARTERY

Benjamin Lipshutz[3] [1917] stated that the GDA arose from CA in 3.7% of cases.

R. M. Jones et al[14] [2001] stated that GDA arose from CA in 0.5% of cases.

Selma Petrella et al[32] [2007] stated that the GDA arose from CA in 6.74% of cases, gastro duodenocolic artery arose from CA in 1.12% of cases.

S. R. Nayak et al[22] [2008] reported a case of CA in which it gave origin to GDA in addition to its classic branches.

Mburu K S et al[18] [2010] stated the presence of aberrant branches in 20.3% of the cases studied among which GDA originated from CA in 3.3% of the cases,

Rajesh B.Astik et al[26] [2011] reported a case where GDA originated from CA.

In the present study in no specimen the GDA originated from CA.

DORSAL PANCREATIC ARTERY

W. Henry Hollinshead[11] [1975] stated that DPA arises from SA close to its origin from CA or may arise from HA or directly from CA.

Pushpalatha[25] [2006] reported the presence of DPA in 2% of the cases studied.

Mustafa Karakose et al[20] [2006] reported a case of 62 year old where the CA trifurcated into DPA, CHA, SA and the LGA originating separately from CA as a first branch.

Mburu K S et al[18] [2010] stated the presence of aberrant branches in 20.3% of the cases studied, among which DPA were present in 14.8% of the cases.

Kalthur S G et al[16] [2011] reported a case of CA where DPA originated from CA in addition to its classic branches.

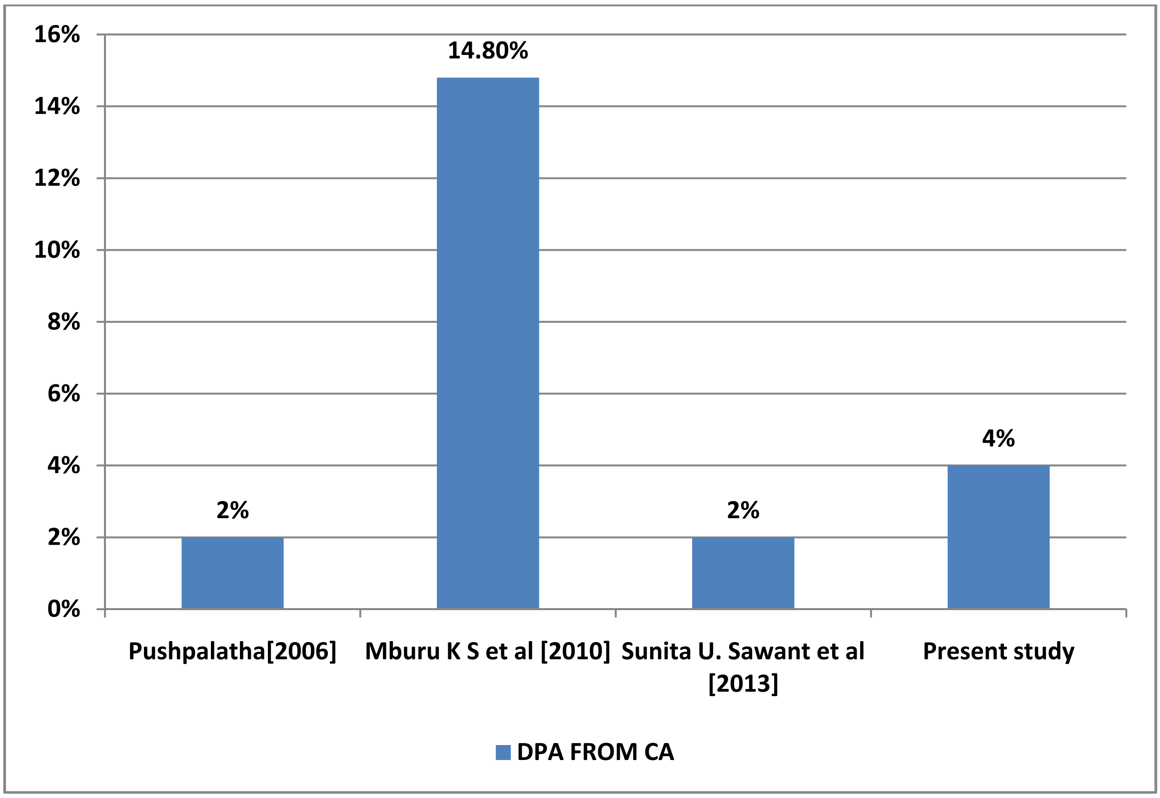
Sunita U. Sawant et al[38] [2013] reported that the DPA took origin from CA in 2% of the cases.

In the present study in 4% of the specimens the DPA originated from CA. The observations made in the present study are similar to the observations made by Pushpalatha and Sunita U. Sawant et al studies**.**

TABLE 26 : INCIDENCE OF DPA FROM CA

Incidence of DPA from CA	Percentage
Pushpalatha [2006]	2%
Mburu K S et al [2010]	14.8%
Sunita U. Sawant et al [2013]	2%
Present study	4%

CHART 23 : INCIDENCE OF DPA FROM CA.



The pancreas is an organ which does not have its own hilum or artery. It is perfused by the arterial arcades which are fed by the branches of the CA and SMA. The pancreatic neck is supplied by the DPA which has a variable origin. Hence its source should be recognized before planning surgeries that require pancreatic head- body transection. A detailed arterial map of its vascular supply should be drawn with the help of diagnostic angiography to minimize iotrojenic injuries.

Conclusion

CONCLUSION

The CA was studied in detail with respect to its origin and branching pattern. The results were noted and compared with that of previous studies. The following are the conclusions derived from the present study.

- The CA originated at the lower border of T_{12} in 64% of the specimens.
- It originated at the level of MAL in 52% of the specimens.
- The mean length of CA was 1.37cm.
- The CA was complete with all the classic branches arising from it in 78% of specimens. The CA was complete in 76% of the angiograms.
- In all the specimens the LGA, SA and CHA originated from CA. The LGA and SA originated from CA in 96% of the angiograms. The CHA originated from CA in 88% of the angiograms.
- Replaced LHA arising from LGA were observed in 4% of the specimens. The CHA quadrifurcated into LHA, RHA, GDA and cystic artery in 2% of the specimens. Replaced LHA emerging

from LGA and replaced RHA emerging from SMA with absent CHA were observed in 8% of the angiograms. The LHA originating directly from CHA were observed in 4% of the angiograms.

- Aberrant branches were reported in 22% of the specimen. Both the LIPA and RIPA arose from CA as independent branches in 6% of the specimens. RIPA alone originated from CA in 12% of the specimens. DPA emerged from CA in 4% of the specimens. Aberrant branches were observed in 20% of the angiograms. Both the LIPA and RIPA arose from CA as independent branches in 4% of the angiograms. LIPA alone originated from CA in 12% of the angiograms. DPA emerged from CA in 4% of the angiograms.

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MASTER CHART

S.No	Level of Origin of CA	Relation to MAL	Length (cm)	Type	No.of Branches	Source of LGA	Source of SA	Source of CHA	Source of LHA	Source of RHA	LIPA	RIPA	DPA
1	Upper Border of L1	Below the level	1.6	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
2	Lower Border of T12	At the level	0.6	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
3	Upper Border of L1	Below the level	1	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
4	Upper Border of L1	Below the level	1.2	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
5	Lower Border of T12	At the level	0.7	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
6	Lower Border of T12	At the level	1.5	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
7	Upper Border of T12	Above the Level	1.9	Aberrant	4	CA	CA	CA	PHA	PHA	Absent	Present	Absent
8	Upper Border of L1	Below the level	1.2	Aberrant	4	CA	CA	CA	LGA	PHA	Absent	Absent	Present
9	Lower Border of T12	Above the Level	1.7	Aberrant	4	CA	CA	CA	PHA	PHA	Absent	Present	Absent
10	Lower Border of T12	Above the Level	1.6	Aberrant	4	CA	CA	CA	PHA	PHA	Absent	Present	Absent
11	Lower Border of T12	At the level	1.7	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
12	Lower Border of T12	At the level	1.9	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
13	Lower Border of T12	At the level	1.3	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
14	Upper Border of L1	At the level	1.3	Aberrant	4	CA	CA	CA	LGA	PHA	Absent	Absent	Present
15	Lower Border of T12	Below the level	1.4	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
16	Lower Border of T12	Below the level	1	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
17	Upper Border of T12	Above the Level	2.1	Aberrant	5	CA	CA	CA	PHA	PHA	Present	Present	Absent
18	Lower Border of T12	Below the level	1.4	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
19	Lower Border of T12	At the level	1.1	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
20	Lower Border of T12	At the level	1	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
21	Upper Border of T12	Above the Level	1.7	Aberrant	4	CA	CA	CA	PHA	PHA	Absent	Present	Absent
22	Lower Border of T12	At the level	1.5	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
23	Lower Border of T12	Above the Level	0.5	Aberrant	4	CA	CA	CA	PHA	PHA	Absent	Present	Absent
24	Lower Border of T12	At the level	1.6	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
25	Between T 12 & L1	Below the level	0.8	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent

S.No	Level of Origin of CA	Relation to MAL	Length (cm)	Type	No.of Branches	Source of LGA	Source of SA	Source of CHA	Source of LHA	Source of RHA	LIPA	RIPA	DPA
26	Lower border T12	At the level	0.4	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
27	Lower border T12	At the level	1.7	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
28	Lower border T12	At the level	1.7	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
29	Between T 12 & L1	Below the level	0.8	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
30	Upper Border of L1	Below the level	1.5	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
31	Lower Border of T12	At the level	1.1	Complete	3	CA	CA	CA	CHA	CHA	Absent	Absent	Absent
32	Lower Border of T12	At the level	1.2	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
33	Lower Border of T12	At the level	1.1	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
34	Lower Border of T12	At the level	1.4	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
35	Upper Border of T12	Above the Level	2.2	Aberrant	5	CA	CA	CA	PHA	PHA	Present	Present	Absent
36	Upper Border of T12	Below the level	1.6	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
37	Upper Border of T12	Below the level	1.4	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
38	Lower Border of T12	At the level	1.5	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
39	Lower Border of T12	At the level	1.6	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
40	Between T 12 & L1	Below the level	1	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
41	Lower Border of T12	At the level	1.2	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
42	Upper Border of T12	Above the Level	2.4	Aberrant	5	CA	CA	CA	PHA	PHA	Present	Present	Absent
43	Lower Border of T12	At the level	1.9	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
44	Lower Border of T12	At the level	0.9	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
45	Lower Border of T12	At the level	0.8	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
46	Lower Border of T12	Above the Level	1.7	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
47	Lower Border of T12	At the level	1.6	Aberrant	4	CA	CA	CA	PHA	PHA	Absent	Present	Absent
48	Upper Border of L1	Below the level	1.2	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
49	Upper Border of L1	Below the level	1.3	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
50	Lower Border of T12	At the level	2	Complete	3	CA	CA	CA	PHA	PHA	Absent	Absent	Absent
			Mean- 1.37										